The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV No. 5. MAY 1953

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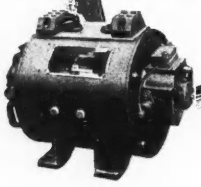

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CONTENTS

	Page
The Blue Pages	153
Consultation and Engineering Design	157
Industrial Television	160
Heavy Rhodium Electroplating	162
The Cavitation-Erosion of Ships' Propellers	163
Voltage Stability of a Synchronous Alternator with Capacitive Loading	168
Pressure Pulsation at the Intake of a Supercharged Internal Combustion Engine	171
Soviet Machine Tools	174
Special Purpose Equipment and Machines	
New Materials, Processes and Equipment	179
New British Instruments	183
British Industries Fair, 1953	187
Swiss Industries Fair, 1953	190
News of the Month	191

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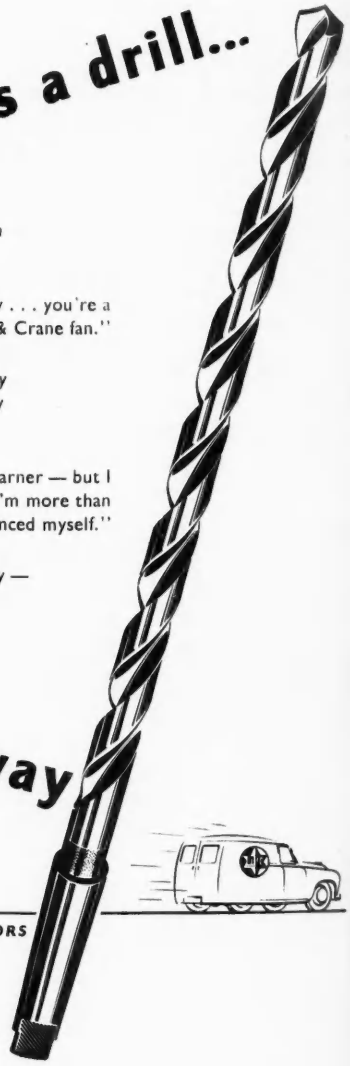

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *SILVER-BRAZING TITANIUM*

Titanium can be joined by induction brazing to practically all commonly used steels and non-ferrous metals if the brazing process is arranged to produce rapid local and uniform heating effect and an inert gas protection is provided. The use of an inert gas atmosphere is necessary because of the ability of titanium to absorb oxygen, nitrogen and hydrogen, and this is detrimental at brazing temperature. A special type of induction furnace developed for this purpose contains the high frequency heating coil, which is dimensioned to produce quick, local and uniform heating of the zone to be brazed. Inert-gas protection is produced by creating a vacuum in the bell jar chamber containing the heating coil and the piece to be brazed, and allowing an inert gas to purge the chamber. The inductor coil is water cooled in order to prevent its melting or warping. When the current is turned off after brazing, the water-cooled inductor coil acts as a condenser and provides an adequate means of cooling the brazed joint gradually to below 800° F before removing the brazed component. Pure silver appears to offer the best characteristics as a suitable bonding agent. It has excellent wetting properties, the alloying effect is negligible, and the joint strength is superior to that obtained with other silver-brazing alloys. Extremely hard and brittle joints were produced when using alloys containing copper, tin, cadmium, and zinc. Joints made with pure silver have a very narrow bonded zone, while silver-alloy brazed joints revealed a wider intermetallic compound zone. Thus, for instance, brazing with the silver copper eutectic alloy results in a needle-like intermetallic compound zone of considerable width.

● *NEW FLOWMETER*

In the technique of measuring the flow of fluids in pipes, it is usual to employ orifices or venturi tubes which allow measurement of the flow rate as a function of the differential pressure set up in the pipe by the orifice or venturi at the point of measurement. In instruments based upon these principles, the differential pressure is frequently transmitted through pipes to the measuring instrument proper, which may be installed at a considerable distance from the point at which the measurement is made. In the case of high pressures this arrangement entails the use of hydraulic piping, which is a decided disadvantage. Moreover, the distance that can be bridged in this way is naturally limited. Other types of flowmeters have therefore been developed in which the response of a flow-sensitive element is made to generate at the point of measurement a corresponding impulse which is more suitable for transmission over a distance. The most suitable system in this respect is of course one employing the electric current in one form or another. Various systems have been developed for the purpose of translating the original measuring impulse with a minimum of error into an electrical signal of corresponding magnitude. One such system which is incorporated, e.g., in flowmeters, employs a diaphragm system in which the force exerted by differential pressure upon the diaphragm is balanced by the force of a solenoid so that the current flowing through the coil of the solenoid is a measure of the differential pressure. This is accomplished by the use of a jet-nozzle system in which a vane moved by the diaphragm admits a variable jet of compressed air into a diaphragm chamber, the diaphragm pressing upon a carbon pile resistor, which in turn adjusts the current flowing through the solenoid, so that the system is balanced.

● *SCALE SOFTENING BY LITHIUM ATMOSPHERE*

At the plant of a leading firm of automobile manufacturers, the problem of removing foundry scale from cast crankshafts was resolved into a question of whether to clean the crankshafts before annealing or after, and both procedures were regarded as too costly with existing facilities. In the former case, normalising scale had to be cleaned after annealing; in the latter, the double scale required extra long cleaning. To overcome these conditions, it was decided to adopt a heating method which would reduce thickness and toughness of the scale on the casting surface. This was achieved by introducing a lithium atmosphere into the furnace. Without changing existing furnace design or construction, two standard lithium vaporisers were attached to each side of the direct fired furnace. These vaporisers are small refractory-lined chambers which are gas fired and can be fitted to any furnace. Running through the middle of the chamber is a rectangular refractory tube in which rests a boat of lithium

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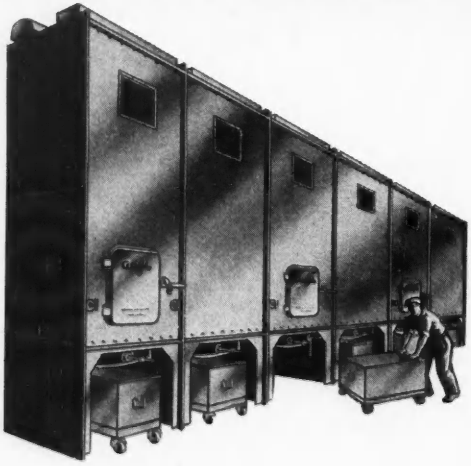

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compound. When the chamber is heated, the compound is vaporised and vapour is picked up by the products of combustion, which enter the tube and are carried into the furnace. The vapour is said not only to inhibit additional oxide formation on the castings, but also to tend to change the character of scale that was on the metal when it was put into the furnace. It becomes relatively soft, thin and flaky. It was also discovered that the atmosphere permeating the furnace chamber to form a coating on the crankshafts, covers alloy parts, such as furnace rails, trays and other fixtures which are in the furnace or which pass repeatedly through it. This coating inhibits normal oxide attack and increases furnace life by 50 per cent, it is reported.

● *CENTRIFUGALLY CAST STEEL TUBING*

Centrifugally cast steel tubing is superior in ductility as compared with statically cast tubing; it is practically free from segregation, is lower in cost, and can be produced to closer tolerances. Of especial significance are its non-directional properties. Thus, equal tensile strengths are obtained in both transverse and longitudinal directions. In addition to circular cross-sections, the external surface can be supplied with special shapes, including elliptical, hexagonal and fluted contours. The bore, of necessity, is always round. Centrifugally cast tubes produced in horizontal moulds permit the selection of alloys not otherwise obtainable. One of the principal difficulties encountered in static castings is the occurrence of voids and porosity caused by the shrinkage which accompanies the transition from liquid to solid. Although the use of risers and feeding heads helps to alleviate this condition, the steel foundry must pour twice as much metal in the average mould as that required for the finished static casting. In centrifugal casting the metal is forced against the mould wall under high pressures resulting from the centrifugal force imparted by the rotating mould. The force generated approximates 75 times gravity and is sufficient to sustain the molten metal on the wall of the mould, precluding the use of a core and resulting in a concentric tube with greatly reduced foundry costs. When the casting is spun, impurities such as dirt, sand and slag, owing to their specific gravity being lower than that of steel, are forced to the inside surface by centrifugal force. Any gas or air pockets are also eliminated. This results in a sounder and more uniform casting.

● *WELD TREATMENT*

In certain types of electric welds difficulties are experienced owing to the excessive cooling speed of the weld leading to shrinkage cracks and consequent failure of the weld. Perhaps an extreme case of this kind is the welding of band-saws. It is reported that, if the electric welding is more or less successful for band-saws of relatively small width, when applied to band-saws of greater width it is completely unsuccessful or, at least, it gives a more or less high percentage of failures. There are reasons for assuming that the welding defects are due, on the one hand, to shrinkage cracks of either visible or microscopic size occurring during the cooling of the weld; on the other hand, the defects may be due to the interposition of oxide particles, or even of an oxide layer caused by the oxidising action of the air during the welding operation. In the specification of a recent patent aiming at improving welding processes of this kind, it is claimed that the aforementioned defects are caused by the very sudden cooling effect produced by the jaws of the machine, where flash welding machines are concerned, or by the rapid cooling of the electrode of resistance welding machines, the jaws and the electrodes being frequently made water-cooled. The proposed solution consists in applying the so-called " martempering " or two-step hardening process, in which the cooling curve of the time-temperature diagram is close to and beneath the curve of isothermal transformation, the cooling to be stopped by adding heat at a temperature higher than the martensitic transformation point so that the temperature can become uniform throughout the piece. Once this has been obtained, hardening can proceed without any risk of producing cracks.

● *CUTTING SPEED CONTROL BY REACTOR*

The maintenance of constant cutting speed is one of the prime requirements in metal cutting technique, and there is of course also one optimum cutting speed in machining any metal. As is well known, an excessively high cutting speed will damage the tool, while insufficient cutting speed diminishes output. An interesting problem in this connection arises in the machining of jet-engine discs. To machine the face of the disc, it is rotated and the tool is moved radially across it. In order to maintain constant cutting speed, the rate of feed of the tool must be made to change as the tool moves toward or from the centre of the disc. In a primitive way, this change in feed rate can be effected by mechanical linkage to a rheostat in the motor field circuit. It is reported that a control employing a small reactor supplies a more satisfactory solution to the problem. To control the machining of a given workpiece, a simple, small cam is cut and a feeler from the reactor, which is contained in a small box about four inches cube, rides on this cam as cutting progresses. As the feeler moves up or down, with its total travel being no more than nine-sixteenth inch, it moves an armature which changes the reluctance of the magnetic circuit of the reactor. Through an electronic exciter this variation in reluctance is made to vary the motor field strength so as to

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. . . stood deserted save for the machine shop foreman crying into his empty glass. "How can I stop my machines breaking down?" he sobbed. The barmaid glumly surveyed the row of bottles he had emptied. "You may not be an authority on machinery," she observed, "but you are certainly an authority on lubrication!" A wild light of hope appeared in the foreman's eye. "That's it," he shouted, "authority on lubrication . . . Tecalemit . . . AUTOMATIC LUBRICATION!" He fled from the room. "Well," complained the barmaid, "perhaps, in future, he'll have the grease to say goodbye!"

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change the speed of the direct current motor, in order to hold the cutting speed constant. In the case referred to, the motor has an eight-to-one speed range, which is obtained solely by control of motor field strength. This speed range is twice the amount ordinarily available by field control and is made possible by providing two sets of windings on each of the four poles.

● *SPONTANEOUS COMBUSTION OF METAL POWDERS*

The great increase in the use of fine metal powders has renewed interest in their pyrophoric property, that is, their ability to ignite spontaneously in air, often in an unpredictable fashion. Since the time when the phenomenon was first described, several theories have been formulated to explain it. Thus, for instance, the phenomenon has been attributed to the presence of finely divided oxide, to an allotropic modification, to the presence of a metastable equilibrium, to heat capacity, or to thermal conductivity. These theories have, however, become untenable in the light of present evidence. The consensus of opinion now is that the pyrophoric behaviour must be attributed to the fineness of division of the metal, and therefore to the amount of free surface of the powder. It has been established that the degree of pyrophoricity is critically dependent upon the particle size. Thus, zirconium powder of average particle size of three microns is highly pyrophoric, whereas zirconium powder of 12 microns size does not catch fire at red heat. Uranium powder retains its pyrophoricity at larger particle sizes than zirconium. In effect, uranium is so much more pyrophoric than zirconium that, whereas zirconium powder is usually stored under water, uranium powder of the same particle size will catch fire under boiling water. It is generally true that the higher the heat of formation of the metal oxide, the larger the particle size may be and yet retain the ability to burn spontaneously. Pyrophoric action, then, results from the inability of the powder to dissipate its heat of oxidation rapidly enough, thus causing its temperature to rise steeply. In the case of iron, nickel and copper, very small particle sizes from 0·01 to 0·03 micron are required to make the material pyrophoric.

● *HEATING IN STEEL MANUFACTURE*

The conversion of ingots to slabs, blooms and billets, and the subsequent reduction of these products to strips and bars requires heating and it is therefore obvious that proper execution of all heating processes is essential if a first class product is to be obtained. Evidently the primary factor is the fuel used for combustion and the subsequent effect of the flue gases on the steel. In the latter respect the effect of sulphur must be taken into account. Sulphur in the combustion gases in either the form of hydrogen sulphide or sulphur dioxide causes excessive scaling. It has also an effect on the surface quality of the rolled steel by making the steel hot short, but it is rather difficult to determine just how intense is the effect. Another important consideration is the moisture content, and this is particularly important on mills which roll to finished size material having a low decarburisation specification. When excessive moisture is present, wet hydrogen is formed which is the worst decarburising combination of all gases present. The air-fuel ratio at the burners of open-fired furnaces has a large effect on the resulting decarburisation and scaling because it directly affects the analysis of the flue gas. A deficiency of combustion air will create a reducing atmosphere where a part of the hydrogen of the fuel is oxidised to water, while the remainder stays in its original form of hydrogen to produce a combination which is a bad decarburiser. With an excess of air, all the hydrogen is converted to water vapour, which is less active as a decarburising agent than wet hydrogen. The excess oxygen present will increase scale formation. For these reasons it is found that the net decarburisation after removal of the scale is at a minimum when using an oxidising atmosphere.

● *GAUGE FOR MEASURING POLYMER PRESSURE*

In the processing of polymers, it is often important to know the static pressure prevailing in the dies, extruders, injection-moulding machines, etc. In experimental work, especially, it is necessary to know melt pressures. For one reason or another, the usual means of measuring pressure are difficult or impossible to use for measurements of melt pressure. These difficulties are due mainly to four requisites of the situation. Firstly, the sensitive element must be small; secondly, the gauge must not be affected by temperature or must be automatically compensated for temperature changes; thirdly, the sensitive element often must be flush with the inside wall of the equipment; and fourthly, the sensitive element and any transmission lines should not fill with polymer. A very simple and compact instrument has been designed which fully meets the aforementioned requirements and is easy to make and to maintain; also its range can be changed quickly. The new gauge consists of three parts: a standard Bourdon-tube type gauge like those commonly used with pressure regulators, a transmission tube and plunger, and an adjusting sleeve to compensate for large changes in temperature. The tubing in the gauge, including the Bourdon tube, is filled with a pressure-transmitting grease, this being a silicone base lubricant. The pressure is transmitted by the grease, while the plunger serves to keep grease and polymer apart. When Bourdon gauges

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● *METAL CUTTING WITH WAX LUBRICANTS*

Recognition of the important role played by polar adsorption in the use of lubricants in metal cutting has led to investigations into the suitability of wax lubricants for this purpose. In exploring the use of waxes in lubrication, it has been clearly proved that specific requirements can be met only by using materials with predetermined characteristics. Indiscriminate employment of waxes is therefore useless and harmful. After the discovery some time ago that one commercial wax product performed surprisingly well in connection with a given task, it was both interesting and disturbing to find that other similar wax products gave poor or entirely unsatisfactory results. A purely empirical investigation of waxes by type and waxes by source resulted in a number of promising starts and an equal number of dead ends, and it became evident that the problem could be solved only by a systematic scientific study of the subject matter involved. It was found that ingredients can be chemically identified, which in combination form a base possessing the properties necessary for high pressure, high temperature lubrication, although these ingredients are not useful if employed individually. When used jointly, however, each of these dissimilar materials augments the use of the other, so that in combination their value is far greater than the sum of their respective values. Nevertheless, wax cannot be considered a replacement for chemically active extreme-pressure ingredients in cutting fluids, nor is it a replacement for pigments or other inorganic solids in drawing lubricants, yet it does enhance the value of both these materials.

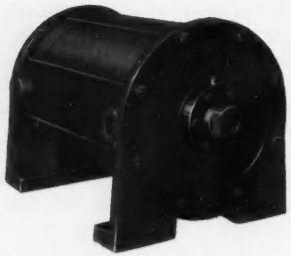
● *CREEP TESTING IN COMPRESSION*

The importance of creep data to high temperature engineering design is well known and appreciated. Unfortunately, it is by no means an easy task to obtain creep data experimentally. To get this information, a test specimen must be subjected to a known stress at a constant temperature for long periods of time. Naturally these test periods vary in length, depending upon the use to which the material in question is to be put. As the permissible permanent deformation by creep is often specified as only one or two per cent, it is often necessary to measure creep rates which are as small as 10^{-7} to 10^{-6} inch per hour. The accurate measurement of such slow creep rates calls for highly sensitive measuring equipment, requires close control of the testing temperature and makes the use of relatively large specimens necessary. Creep tests are usually carried out as tensile tests, but it has now been suggested that compressive testing offers considerable practical advantages. The question arises whether compressive testing and tensile creep testing are comparable; strictly speaking, this is not the case, as, for instance, the extent of deformation in the primary creep stage is larger in the compressive test than in the tensile test. However, even so, the correlation between compression and tension creep is such that, for metallic materials, compression tests which can very easily be carried out on miniature specimens can be used to give an accurate comparison between the creep rate at elevated temperatures of various alloys, or of various specimens of the same alloy.

● *DUCTILE METAL POWDER PARTS*

The development of a new metal powder product with unusual physical properties has just been announced. The new product, which is a ferrous-base material, is claimed to be the first powdered metal composition which possesses both ductility and strength comparable with the corresponding properties of low carbon steel. In addition to its remarkable ductility, the new material is reported to have several other important advantages over more conventional powdered-metal products. Among these, its greater ability to withstand impact and bending, its increased ability to withstand temporary overloads, and its much wider range of applications appear to be outstanding. If desired, the material can be hardened by heat treatment, including carburising, cyaniding, or nitriding. By using a carefully selected heat treatment, hardnesses up to 60 Rockwell C are claimed to be obtainable, although at some sacrifice in ductility as compared with non-heat-treated, low-carbon materials. Alloyed powders may also be used, if desired, to obtain a greater tensile strength. The press-formed and sintered product can also be infiltrated with copper, but it is considered that most applications will require neither heat treatment nor alloy additions. The ductility of the material is 2½ to 3 times greater than that of other iron powder products. Thus, while the best ductility of a conventional steel powder product approximates to 2 per cent elongation in one inch, the new material, it is stated, exhibits ductilities ranging from 5 to 30 per cent elongation in one inch. Typical uses of the material include industrial machinery and automotive components, and parts for household appliances, textile machinery, washing machines, etc.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.



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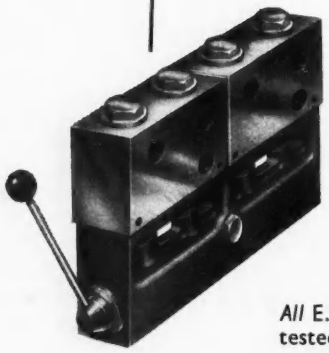

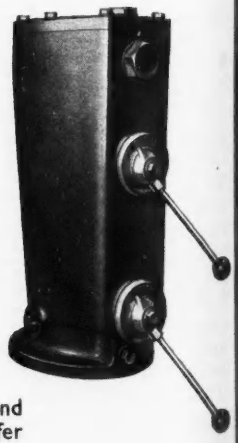

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Consultation and Engineering Design

By J. S. SHAPIRO.

MEN have always shown two attitudes to advice received from others. Good advice is highly valued, yet we often say " So-and-so can give you nothing but advice." Consultation in technological pursuits has suffered from the same contradiction.

The story is told of a consultant who pestered an executive for an assignment until he was given one. " Advise me," said the executive, " how to get rid of you."

Happily or unhappily, consultation is usually overshadowed by human relations. Yet no one can assert today that consultants are merely a nuisance which cannot easily be ignored. Their case is as strong as their attentions are insistent.

The thoughts which follow are dedicated to a more narrow proposition. Engineering design should, in the interests of industry, sometimes be performed by independent professional men or teams, as much as architectural design or legal work is often entrusted to professionals of an independent status. In support of this proposition, it is necessary to discover the factual foundation for consulting services in the patterns of specialisation of modern industry, and to crystallise the profession of design engineering.

PATTERNS OF SPECIALISATION.

The art of industrial creation is complex and versatile. Men achieve excellence through perfection of individual skills. The conflict between the need for versatility in industrial creation and the gift of single-mindedness in men has led to the division of labour so typical of our society. This fact is neither new nor disputed. The " specialist " commands admiration, arouses regret and even invites irony (particularly in sanitary engineering).

It is not always understood, however, that the division of labour, as it exists, does not follow a single rule. The prominent meaning which the public associates with the conception of the technical expert is a man who specialises in a product, such as motor cars, shoes, baby powder or underwear. It is important for our theme that several other dividing principles exist. Each is based on a different aspect of productive and creative labour. One such aspect is the method of production. Thus, men may be experts in baking, weaving, or smelting. Raw materials furnish another aspect. There are specialists in milk, oil, wood or steel. Yet another principle of specialisation is found in administrative control. Some men are good in charge of an apprentice school, others in running a post office.

In some conditions, environment exerts a decisive influence and becomes the overriding principle of specialisation. Thus, we have seamen, mining engineers, farmers, each a jack-of-all-trades in an overpowering environment. Finally, we have the professional classification, such as that of solicitors, printers, mechanics or accountants.

Which of the many patterns of specialisation is adopted depends entirely on the technological methods and the administrative structure of the industry. Hence, patterns of specialisation change as much as technology and organisation.

Hitherto, the ruling pattern in industry has been the specialisation between companies and firms by the product, or class of products (having a common raw material, production method, or use) and specialisation by trade or profession inside the corporate unit. Industrial undertakings obeying this pattern keep on their own staff all the experts needed to create and manufacture their product and to run their establishment. Yet this pattern of specialisation is neither universal nor inevitable. It is by no means always natural or desirable.

It is important for the progress of modern industry to recognise, not, as is often asserted, the merit of one pattern to replace another, but the need for an increasing variety of patterns of organisation and specialisation. Among these, we are concerned in this context with the separation of engineering design from the business of producing and selling. Such a separation, whilst occasionally inadvisable or even impossible, is often a matter of choice but sometimes becomes vital for the progress of a company or a branch of industry.

Before we examine the reasons for this belief, it is advisable to define more closely the consulting service advocated in this discussion by explaining its distinctions from other forms of consultation.

TYPES OF CONSULTATION.

The term consultant is broad and can be misleading. The only thing common to all consultants is their relation to their clients. In other respects they fall into different categories. One distinction must be made at once. Consultation may consist of offering advice, and, if so, does justice to its name. However, much, if not most, consulting activity consists essentially in supplying the results of work carried out. In such cases, the consultant offers services and facilities rather than advice. This distinction is not necessarily a dividing line between persons, but between forms of activity. Failure to recognise it has been perhaps the greatest single cause of disappointment with consultation in all its branches. To help in their decisions, executives may require an adviser, who may be a solicitor, an accountant, an industrial consultant or a crystal-gazer, but those who need the service of professional work carried out to their instructions should choose consulting organisations capable of offering the required facilities.

Traditionally, the term consulting engineer denotes one of two things. For generations, " consulting engineers " have been entrusted by clients from abroad with the task of selecting, ordering, chasing and inspecting of equipment such as railway materials or gas plant. The other type of consulting engineer is either the structural engineer, the architect of civil engineering structures, or the mechanical engineer, the architect of mechanical installations in building construction. Neither of these types of " consultation " is the subject of this discussion. As institutions, they are accepted and need no advocacy.

Two further classes of consultants are of more recent origin and nearer to our theme because they operate in manufacturing industry. These are the consultant on the organisation of production and the consultant on

sales, usually concerned with market evaluation and publicity. These two classes have won wide acceptance even here, following their triumphal rise in the U.S.A.

In this context, however, we are concerned with the task of designing products of the engineering industry. In an age of specialisation it should be easy enough to distinguish between the functions of design, production and sales, yet the distinction of design is often ignored.

Some examples will illustrate the point. The design of containers for cosmetics is almost wholly dictated by the improvement in sales appeal which the container lends to the product. The design of vacuum cleaners is so strongly dominated by the task of producing a complicated article cheaply, that the production engineer's advice ought to be decisive. The kind of knowledge which counts much in the design of furniture is the experience of the buyer of timber because the degree of utilisation of a variable and capricious raw material decides the economics of this industry.

None of these extreme examples is characteristic of the engineering industry. Moreover, the trend of modern life is the emphasis on design as the guardian of the true function of the product, namely, its use and enjoyment by Man, the Customer. Increasing efforts are made to divest raw materials of their variability, or to find uniform substitutes. Under the impact of pressing needs, sometimes the needs of war, where no sacrifice from the best-known design is acknowledged by the enemy, production men have learnt to exercise their ingenuity to free the designer from limitations. Even publicity men in the engineering world are showing more interest in the quality of the product ensured by design and less in high-pressure salesmanship. All these trends are nowhere more strongly in evidence than in the United States, where only a generation ago production was a religion and sales promotion a holy ritual.

In arguing the rising importance of design, no suggestion is implied that the industrial design of engineering products should be divorced from all the other aspects of industry. It is argued that, at present, the greatest prospects of improvement in quality and efficiency lie in making design the arbiter between them all.

In some industries, design development has already become a dominating activity. Aircraft construction is an excellent example, but only one of several. In other industries, such an outlook is overdue, often retarded by lack of facilities. Unfortunately, just as often the absence of design development must be attributed to a failure of managements to realise the need for improvement.

If iron ore deposits and coal seams like those found in the United States were available in Great Britain ; if the conditions of the American market were transferred over here and permitted the concentration of production on uniform qualities and large quantities, the chief lesson to be learnt from abroad would have been the methods by which productivity is attained in America. In fact, these benefits are no nearer than are rich goldfields in Surrey or uranium mines in Cornwall. Nor are they really necessary, for the broad trend of modern industry favours the living inventive genius which increasingly masters the differences of wealth founded upon the dead deposits of the past. If the attitude here expressed were more fully appreciated on a national scale, it would have been realised that visits by design teams would have produced much greater returns than the journeys of productivity teams to the States.

Before entering further into the essence of design engineering as a profession, some confusion has to be cleared up on the subject of " industrial design." This has become an accepted term, and the profession is flourishing in the U.S.A. and is beginning to come into its own in Great Britain.

The avowed task of the " industrial designer " is the styling of industrial products, such as tea pots, car bodies, or covers for sewing machines. The practitioners of industrial design are mainly artists devoted to useful objects, with some knowledge of production and an interest in marketing. Their engineering background is usually secondary.

It is not the object of these notes to discuss the meaning of industrial aesthetics and good styling. There is a strong body of opinion which advocates " functional design " and admits no independent aesthetic criterion beyond the satisfying fulfilment of purpose. Much of the activity of the so-called industrial designer is devoted to products wherein functions are judged by commonsense and require no disciplined science of engineering. Here we are concerned with industries where design cannot be separated from engineering science.

Design Engineering as a Profession.

To use a common description, the division of labour into professions can be described as a horizontal division, distinguished from the vertical division based on products. Laymen find this distinction difficult to comprehend because their idea of the technical specialist is based on the magic effect of the Specialist's familiarity with detail. The man who knows which screw to turn to make a broken-down engine work again, the man who possesses the " know-how," instantly impresses as the true professional.

It is the essence of the designer's calling that he does not know, but merely has the skill to find his way. Even in manner he is often hesitant. And yet the recognition of design as a specialist's occupation is by no means remote.

In architecture, design activity is recognised as a distinction separating the architect from the builder, and uniting the architects of dwellings, schools, hospitals and factories. Nevertheless, the comparison is not entirely satisfactory.

In engineering creation we include all the contributions to the development of a product ; so much so, that the phrase " Product Engineering " had to be widely adopted.

Technical design is the process of creative synthesis of a product from familiar elements and knowledge, derived from scientifically controlled experience. The synthesis must be preceded by a thorough appreciation of the design problem, through analysis. Technical design is unquestionably an art as much as any other design. Acceptance of design as an art is not only compatible with, but is truly married to, the use of science. We might say that design is a process wherein the application of science becomes an art. It is interesting to observe that all good design appears to consist of simple steps.

The ability to complete successfully the cycle of analysis and synthesis, an ability which entails some inspired feeling for harmony with nature, is that which distinguishes quality of design. The good designer is not the man who merely knows " everything about nothing."

Some readers may think that what are here stated to be the designer's activities are really the prerogatives of the inventor. No one has yet succeeded in defining invention. The exercise of ingenuity and the inspired marshalling of elements to accomplish a set task is the designer's calling.

In the modern world, the designer's vocation is seldom carried on by a single man, or even a single team. With the further subdivision of design specialisation, each operation forming part of the process of design becomes even more characteristic of the profession of designing, and less of the product designed.

Anyone with design experience in diverse and seemingly unrelated fields must become impressed with

the real kinship of design procedures practised in the development of totally different products.

It has been stated on very high authority that present conditions in this country dictate not so much the promotion of research as the advancement of the application of research to industry. The apparent hesitation of British Industry in developing new products to a production stage astonishes all sympathetic observers.

It is unreasonable to seek for a single cause of a phenomenon so complex, so profound and so challenging for the future. Yet it is arguable that the dominating cause has been the lack of recognition of Product Engineering as a profession.

Benefits to Industry.

If the rising importance of design in industrial work is admitted and the profession of design engineering fully recognised, the benefits which industry will reap by making use of consulting services are easily seen. Some of these have general validity, others are of special significance in this country. The general advantages will be mentioned first.

In Product Development the opportunity and urge exist to import the spirit and methods of the more advanced branches into the older and more conservative fields. Thus, the habits of enquiry current in aeronautical design can be employed to great advantage in a variety of industrial applications. In this connection the benefit derived from the existence of independent Product Engineering teams is their unique ability to maintain a cross-flow of references between the specialised achievements in engineering. They can, as it were, specialise in generalities. There are numerous examples of industries desperately awaiting a development accomplished long ago in another branch.

In an activity based mainly on brain work it is not mere sentiment to study this instrument and understand its laws. Such a study renders some valuable observations. The majority of technicians tend by nature to develop either purely practical or purely theoretical inclinations. Between these two groups there seems to develop a widening gulf, even outright suspicion and animosity. Positive action is needed to bridge this gulf between theory and practice. Men with the ability to build such a bridge are rare ; they must often be sought outside a particular organisation.

A reversal of the hole-and-peg metaphor illustrates our argument. The only thing to do with square pegs is to find square holes for them, rather than seek round pegs for the round holes prepared in advance. There are many men of talent who cherish their individuality above all. Such men will do their best only in conditions of independence. Independent Product Engineers can combine the services of supplying the results of work and of selling advice. No human being can confine himself to giving advice without losing his capacity to act, until eventually he is classified under the rule : " those who can, do ; those who can't, teach."

Advice will be most valuable when concerned with the organisation of design development. While an element of individuality will always reside in creative activity, it is entirely possible to eliminate many common and very costly mistakes which are found to occur repeatedly in all development work. Such an adviser must be reared in product engineering, not production control. He can be found only in the ranks of independent development experts.

In British Industry much industrial activity is spread over a large number of small and medium-sized undertakings, whose resources are insufficient to support large development teams and accommodate every kind of expert knowledge within their own walls. The need arises for the availability of specialised knowledge on loan.

Too much creative work in engineering is, in this country, relegated to the back room, and governed by conditions which have produced the well known notice :

" You don't have to be crazy to work here, but it helps." No nation can maintain leadership in industry unless it offers the creative technician a status and reward beyond that given for non-creative competence.

Those are the fruitful, felicitous, and lasting benefits which industry can and, it is hoped, will derive from its co-operation with independent designers. In reality, of course, we usually find accidental causes at work which determine day-to-day decisions.

In practice, the most frequent conscious reason for calling in a design consultant is his personal reputation which cannot otherwise be exploited. In many cases, consultants are called upon simply to deal with the overflow of work. Sometimes managements feel that the bringing-in of an outsider is necessary in order to keep their own staffs " on their toes." On the whole, present standards and practices of taxation encourage consulting services.

Naturally, consultants will make use of every breeze which blows into their sails, but will do well to adapt their policy to lasting trends in industrial organisations and unalterable qualities of human nature. They should resist, in particular, the fallacies of fashion and refuse to transgress the limits of their true competence.

Code of Behaviour and Scope.

The term " consultation " has become highly misleading when taken in its literal sense. To suggest that the function of a consulting structural engineer employing several dozen qualified draughtsmen and stress analysts is to give advice is wholly unreal. The distinction is important when it concerns the code of behaviour in professional life. The design consultant for manufacturing industry goes a step further than the structural engineer. He often embodies his design in a prototype and performs tests upon it.

The essential difference between a consultant in the strict sense of the word and the independent engineer engaged in design and development is that, whilst both sell competence and time, the foundation of the former is integrity and that of the latter is performance. The difference is based on fact and not merely on attitude. The physician cannot be judged by his performance until it is too late, but the baker has only to display his wares.

There is essentially no distinction between a consultant in industrial design and an organisation or team engaged in the development of engineering products, whether these are commissioned or not. The whole structure of etiquette which has arisen around the consulting business is not really applicable to the consultant in design engineering, even less than it is to the services of a modern architect or civil engineer. Whilst the latter still has some good reasons to cling to a tradition with much sound sense in it and to seek modification through an elaborate set of rules and through the practice of honouring certain regulations by breach rather than observance, the design consultant in manufacturing industry has every reason to avoid attachment to a tradition moulded by conditions most unlike his own.

Thus, it is difficult to see justification for the prohibition of direct publicity, a prohibition with a moral foundation in those professions like medicine or law, which take care of human misfortune. Nor is it easy to see why it should be more *recherché* to charge for time or a percentage on the work performed than to seek a reward determined by technical or commercial success.

If the young branch of consultation in engineering design and development accepts such restrictions it is an example of a senseless slavery to an outmoded word.

The field appropriate to Product Engineering consultants, though clearly distinct from others mentioned in this article, is nevertheless wide, and needs sub-

division. Rarely will one organisation, let alone one man, be able to claim competence in all its branches. No such organisation in practice will be a pure embodiment of the argument and ideas put forward here. Each organisation and individual will have roots in particular experience and be subject to ties and connections of a concrete nature which will attach them to particular products, materials, fields of application or environments.

Some readers may not realise the scope of product engineering and the variety of its contributing branches, all of which add up to the development of an engineering product. Some representative examples are given below. Each may be undertaken separately or in combination by an independent team of design engineers.

Library research.
Technical liaison with government departments, research establishments, trade bodies and professional organisations.
Analysis by methods of engineering science.
Preparation of design drawings.
Supervision of the manufacture of prototypes.
Execution or supervision of prototype testing.
Application of test instrumentation aids.

In product engineering there is also room for consultation in the narrow sense, the giving of advice on several aspects of product development work proceeding inside an industrial organisation. These aspects can be of many kinds :

Administration of research and development.
Organisation of design departments.
Use of testing methods.
Prospects of inventions.
Patent protection policy.
Technical aspects of sales promotion.
Fields of employment for materials.
Financing of new developments.

Product Engineering consultants may range from one-man businesses to sizeable institutions bursting with wires, lenses, machines and glassware. But when gadget-mongery replaces brains, a designer has forsaken his true vocation. The creation of form will always remain the noblest tool of the designer. Metallurgy, chemistry and a variety of electronic and other devices are, in the last resort, no more than clay in the hands of the potter.

If these lines have helped to recognise healthy trends, and if this recognition leads to the consideration by those in command of a more extensive use of consulting services in engineering design, they will have done their share in promoting the progress of the engineering industry.

U. S. A.

Industrial Television

By G. H. WILSON. (From *Electrical Engineering*, Vol. 72, No. 2, February, 1953, pp. 125-130, 14 illustrations.)

Television unquestionably has a place in industry and, even at this comparatively early stage of its development, its increasing acceptance, as well as the uses now visualised for it in the future, indicates that its potential for industry is probably greater than that to be realised in broadcasting transmission and reception.

Radio television had already become familiar to the public by the time industrial television had been initially developed, and thus gave rise to a tendency on the part of prospective users to judge the latter on the merits and shortcomings of the former. This was an unintentional injustice to both, as the conditions encountered industrially, as well as the purpose to be served, differ vastly for the two applications. Television in industry is a " work horse," not a " show horse," and performs the following basic functions :

(1) It reduces accidents, (2) reduces operating costs, (3) reduces capital investments, and (4) under certain conditions it provides greater intelligence than can be gained by direct observation.

A television system is an electro-optical device, in which a high picture quality can be achieved only at the expense of great complexity and hence, high price and maintenance cost. The main task in the design of industrial television was, therefore, to find the optimum point of balance between these opposing aspects.

It was found that by employing a long-life cold-cathode tube, without a filament or electron gun, with a consequent slight reduction of picture definition, television equipment could be evolved which would operate on a continuous basis without supervision ; would remain in adjustment, once set ; would not, in most cases, require skilled maintenance personnel ; would represent an operational cost comparable to that of an average control panel instrument ; would be comparatively insensitive to temperature fluctuations and vibrations ; and would produce a medium-definition picture instantaneously and continuously at distances up to 1500 ft between camera and viewer, and at greater distances if an amplifier were provided.

In the case of the " Utiliscope," these characteristics were achieved by sacrificing some of the sensitivity which is so all-important in radio television. A cold-cathode sender tube, or image dissector, has been developed for industrial application. An average industrial television installation is shown schematically in Fig. 1. A camera employing the image dissector is placed in a fixed position, viewing an object or process, the position and/or movement of which can be viewed without need of lens readjustment. Close by the camera, but as far as 100 feet away if necessary, is the camera power supply. A coaxial cable connects the transmitting section with the receiver, which is installed at the control position. This arrangement is typical of installations used in the electricity supply industry for indicating the water level of large boilers at the operators' positions, and its purpose can best be described as " remote vision."

The water level in the boiler drum can, of course, be indicated by telemetering, but accidents in several power stations have shown that this method is not entirely reliable. Alternatively, the water level can be indicated by " remote vision " using mirror arrangements. This method however, also has its limitations, apart from the fact that with increasing distance, the size of the picture decreases. Furthermore, transmission of the gauge image by mirrors requires duct work and the provision of line-of-sight openings, resulting in a far more expensive installation than a television system. Also of importance, in this application particularly, is the fact that while the operator must stand in a precise spot to observe mirror transmission of a gauge image, he is not so restricted when television is employed. A reliable indication of water level can be seen on the receiver screen from anywhere within an arc of 125 degrees, and, in the average case, up to a distance of 20 feet and more.

The latest type of " Utiliscope " equipment comprises a dual lens arrangement which, while not needed for gauge observation, has proved valuable in other applications in industry, and is completely controlled from the operator position.

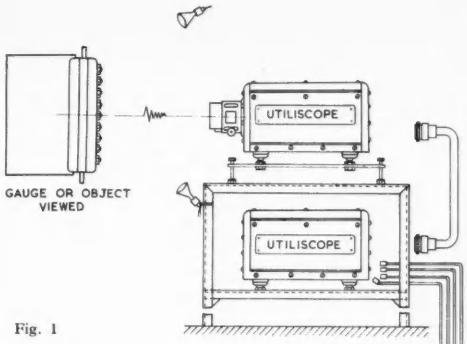


Fig. 1

Television is also used for remotely observing boiler furnace interiors, one of the most rapidly expanding applications at the present time.

Combustion conditions in the furnaces of the boilers of Port Jefferson power station in the U.S.A. can be watched continuously on television screens* located in the boiler panel in the station's control room. The objectives in developing this application of television were: (1) to control whether, preparatory to lighting off, all ignition torches operated from the control room are ignited; (2) to control whether ignition has taken place and whether it is stable; (3) to recognise faulty operation of burners during operation on load; (4) to recognise loss of ignition at any time; (5) to recognise unsatisfactory combustion; and (6) to permit observation of burners and combustion conditions not readily analysed by other means.

The television camera is mounted so that the lens is over a centrally located window of 3 in. diameter in the furnace roof, see Fig. 2. For these windows, water cooling and air cooling systems have been developed. The viewing stations are located at the top of the furnace near the point where the hot gases enter the superheater bank and the temperature is 2000° F. Combustion conditions can be seen down to the burners, a distance of approximately 55 ft.

In one of the two installations the camera lens is protected by a water-cooled window mounted in a chamber supplied with compressed air. Air passes through an annular opening and across the bottom glass of the water-cooled window to prevent discoloration of the furnace side of the glass. A closed circulating system is employed. Water from a storage tank is circulated by a motor-driven pump through a small heat exchanger, through the window, and back to the tank. If the pump fails, natural circulation of the water cools the glass sufficiently to protect the camera for a short period. In the second installation the camera lens is protected by an air-cooled window supplied with about 45 cfm of air at 1 psig. The window glasses can be removed, cleaned and replaced quickly and easily without the use of tools or gloves. Air is supplied by a small motor-driven blower. In the event of motor or blower failure, an alarm in the control room is actuated and an alternative air supply opened automatically.

Electrical maintenance on the unit, which has been in operation since April, 1951, has been nominal. There have been no failures of camera or picture tubes. Some time has been required for adjustment of camera and receiver, the major part of which was spent on adjusting the focus coil for the picture tube. Based on present experience, it is expected that a preventive maintenance inspection every three months will keep these units in satisfactory operation.

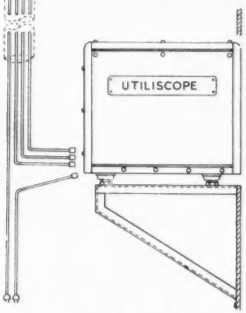
* See *Electrical World*, Feb. 9, 1953, pp. 92-95. Ed. E.D.

Other power plant uses of television include the observation of chimney emissions, and it is contemplated to use it also for the control of the entry of unauthorised persons, the regulation of remotely controlled vehicular traffic, and the remote observation of meters and equipment at unattended installations.

It has been shown that industrial television can be adopted for use with carrier systems and with u.h.f. point-to-point transmission equipment.

Applications in other industries comprise the remote observation of machining operations on high explosives and the handling and testing of bombs and ammunition. In the steel industry, television is used for the control of a continuous billet-pouring process which thereby can be centralised in the hands of one man. Several separately located processes can, of course, be simultaneously observed by one man.

An application adopted in a tube mill provides for the control of the rate of feeding of a cooling furnace, so that pile-ups which might impair the control of uniform cooling can be eliminated without the necessity of stationing an extra man at the furnace entrance. The camera and operators are approximately 100 feet apart, making image transmission by the use of mirrors unsatisfactory.



Other applications comprise the observation of models undergoing wind-tunnel tests, and the control of large-scale scrap paper weighing operations, where

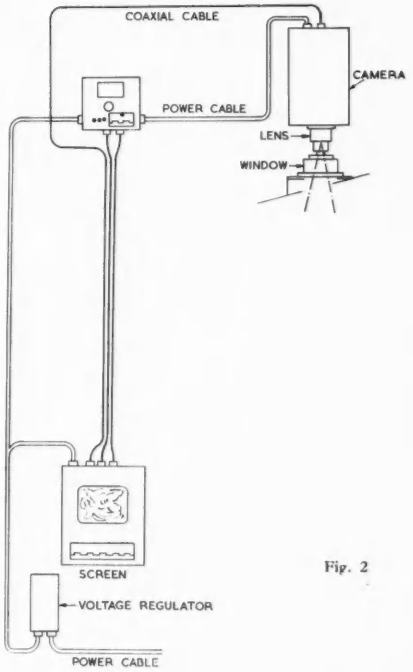


Fig. 2

information from three separate platforms can be handled by one man instead of three which would normally be required.

Taking into account the very numerous and varied applications of which industrial television is capable, its further development can be confidently expected.

U.S.A.

Heavy Rhodium Electroplating

By A. M. WEISBERG. (From *Materials & Methods*, Vol. 37, No. 3, March 1953, pp. 85-87, 3 illustrations.)

HEAVY electro-deposits of rhodium are increasingly used in electrical and mechanical engineering. Rhodium remains free of tarnish and strongly resists chemical corrosion. It is one of the hardest electroplating metals (775 to 820 Vickers) and is extremely wear-resistant. As it has also good electrical properties (resistivity at 64° F : $4{\cdot}51 \times 10^{-6}$ ohm-cm, temperature coefficient of resistance : 0·00242/°F, relative attenuation (copper = 1) : 1·46, specific magnetic susceptibility at 64° F : $1{\cdot}11 \times 10^{-6}$), it is particularly suitable for switch and relay contacts, commutators and sliding contacts, and for all components subject to extreme wear, highly corrosive atmospheres and high temperatures. The cost of deposition is estimated as approximately $0·18 per 0·000001 in. per sq ft.

Rhodium is practically unworkable by normal metal-working techniques. Since 1930 it has been used for electroplating, but the thickness of deposit has usually been limited to less than 0·00001 in. Heavier deposits cracked and had dull, rough surfaces and poor adherence. New techniques now produce bright crack and pore-free deposits up to 0·001 in. thickness.

Rhodium can be deposited directly over silver, nickel or gold. It can also be deposited over copper, brass, steel and other metals and alloys, but it is advisable first to apply a thin deposit of silver, nickel or gold to prevent a build-up of foreign metals in the rhodium bath. Where rhodium is used for its hardness, nickel has been found the best base. For electrical components, silver or gold bases are generally preferable.

APPLICATIONS.

Rhodium is more corrosion-resistant than gold or platinum, and its electrical resistivity is less than that of platinum or palladium. The complete absence of tarnish on a rhodium surface makes it particularly suitable as a contact surface, where low and perfectly stable contact resistance is necessary. Oxide and sulphide films normally present on contact metals form non-ohmic contacts that give partial rectification, which is a vexatious problem in input circuits for very high frequencies. Heavy rhodium contacts have solved many of these problems, as rhodium-to-rhodium contacts maintain an ohmic contact resistance under all atmospheric conditions.

Alarms and safety devices, working often in corrosive atmospheres, must be cleaned frequently to keep the contacts in proper working condition. Rhodium-plated contacts, however, remain bright, clean and free of surface corrosion.

Moving electrical contacts require a contact surface that is ohmic, smooth, hard and anti-galling. Heavy rhodium plating meets all these requirements. Its hardness ensures that even 0·0001 in. coatings will outlast other metals and alloys under conditions of high pressure or high speeds.

Certain slip-rings are required to carry step voltages, or complex, information-carrying waveforms. Rhodium is used with advantage on such components, as it generates a very low r.m.s. noise voltage, and can transmit a signal substantially unchanged in form.

Rhodium has also been used successfully on valves, gauges and flow meters in high-purity water systems. With the new techniques for giving crack-free heavy rhodium deposits, it is likely to become widely used as an anti-corrosive coating in systems handling compounds that are poisoned by fractional parts per million of copper, iron or other cations.

PLATING PROCESSES.

Techniques for producing heavy deposits of rhodium demand extreme cleanliness, but are quite straightforward, and less exacting than many types of electroplating. Tanks for rhodium plating are constructed of pyrex, plastic or polyvinyl chloride elastomer lined stainless steel. Heating should be indirect, though fused silica immersion heaters can be used.

Articles for heavy rhodium plating are cleaned and activated by standard plating techniques. Great care, however, must be taken to ensure that the work is chemically clean, as rhodium baths are easily contaminated. Partial or uneven activation must also be guarded against, as rhodium, once deposited, cannot be stripped. Plating rejects must therefore be kept to an absolute minimum, particularly if the parts to be plated are valuable.

The composition of the rhodium bath and the conditions of operation vary widely with the shape of the part to be plated, and the desired thickness. For plating 0·00001 to 0·001 in., the range of rhodium metal content of the bath is 8 to 40 grams per U.S. gallon. The metal is added to the solution as the sulphate complex. The range of acid concentration of the bath is 50 to 555 cc of chemically pure sulphuric acid per U.S. gallon. Other operating conditions are :

Temperature	..	100 to 120° F
Agitation	..	10 to 100 fpm across the face of the work
Plating time	..	1 to 60 minutes
Current density	..	5 to 100 A/sq ft.

Insoluble platinum anodes are used. For blind holes or deep recesses, it is sometimes necessary to use inside platinum anodes and to pump the solution through or against the work.

Where a close tolerance on the thickness of deposit is specified, it is advisable to use an ampere-hour meter to record the quantity of rhodium deposited. With such a meter, and close chemical control of the solution, deposits can be accurate to within 5 per cent of any desired thickness. For thin deposits and less critical work, it is possible to rely on automatic timers, or easily read clocks and ammeters.

The rhodium content of the bath is controlled by colorimetric or standard gravimetric methods, and the acid concentration is checked by titration. The rhodium bath contains only rhodium, sulphate and hydrogen ions, and there are no complicating factors in chemical analysis.

RHODIUM THICKNESS REQUIREMENTS.

Application	*Thickness*
Decorative finish	$1 \text{ to } 5 \times 10^{-6}$ in.
Tarnish protection	$5 \text{ to } 10 \times 10^{-6}$ in.
Light duty electrical contacts ..	$15 \text{ to } 20 \times 10^{-6}$ in.
Heavy duty electrical contacts ..	0·0001 in.
Infrequently used contacts ..	0·0001 in.
Corrosion protection	10×10^{-6} in. and over
Severe corrosive conditions ..	20×10^{-6} in. and over
Severe wear electrical contacts ..	0·00025 in.

The Cavitation-Erosion of Ships' Propellers*

By J. BALHAN. (From *De Ingenieur*, Vol. 65, Nos. 6 and 7, February 6 and 13, 1953, pp. W29-W40, W41-W45 and W52, 16 illustrations.)

THE trend towards increased ship and propeller speeds, in recent years, has made research on cavitation an urgent matter. Broadly speaking, cavitation is a state of flow of a liquid in which the pressure decreases to a vacuum at certain positions. This enables the liquid to evaporate and form vapour pockets.† According to Bernoulli's law, these low-pressure zones are also the regions where maximum velocity of the liquid is reached, and Kirchhoff's law indicates that these regions are situated at the surface of solid bodies.

The flow pattern around a propeller profile is disturbed by these vapour-filled cavities, and this affects the propeller thrust and torque, with a consequent decrease in propeller efficiency. Erosion is in many cases a further result of cavitation, which can also lead to vibrations and rupture. It is therefore of the utmost importance that cavitation be avoided.

The conditions for cavitation can be analysed as follows :

Let p_a and V_a denote the actual values of pressure and resultant velocity occurring at a point on a blade profile, p and V being the corresponding values for an undisturbed field, and e the pressure of saturated water vapour. Then, in order that cavitation may occur, it is necessary that

$$p_a \geq e$$

or $$(p - p_a)/(\tfrac{1}{2}\rho V^2) \leq (p - e)/(\tfrac{1}{2}\rho V^2)$$

where ρ is the mass-density of water. Applying Bernoulli's law

$$p - p_a = \tfrac{1}{2}\rho V_a^2 - \tfrac{1}{2}\rho V^2$$

we obtain

$$\frac{\tfrac{1}{2}\rho V_a^2 - \tfrac{1}{2}\rho V^2}{\tfrac{1}{2}\rho V^2} = \frac{\Delta p}{q} \leq \frac{p - e}{q} = \sigma$$

where σ is the "cavitation factor." These relations show that with increased V-values, i.e., increased propeller speeds, the decrease in pressure becomes greater and, furthermore, that the blade tips are most exposed to cavitation, since maximum velocities are reached at the blade tips.

Fig. 1 shows the pressure distributions around a Göttingen aerofoil type 387 propeller blade element, for angles of incidence $\alpha = +8{\cdot}6°$ and $-3{\cdot}1°$, respectively. As a rule, the propellers designed by the Netherlands Marine Engineering Research Station are based on diagrams for systematic propeller series.

A number of theoretical and practical investigations of cavitation problems has been carried out at the Marine Engineering Research Station** and a vortex theory applicable to modern ships' propellers has been developed.‡ This theory includes design considerations for propellers of high-speed merchant ships and warships. Comparative results for the latest designs and propellers of the B-series show a considerable improvement as regards cavitation-reducing properties.

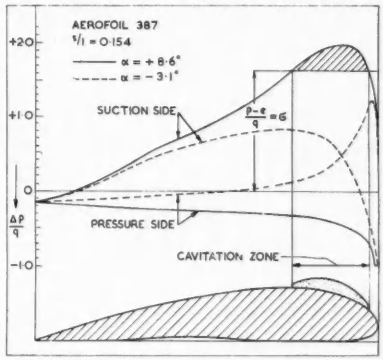


Fig. 1. **Pressure distribution of an aerofoil type profile.**

A drawing of the cavitation tunnel of the Marine Engineering Research Station is given in Fig. 2 (a description is published in the book by van Lammeren, Troost and Koning†). As usual, propellers with different types of blades on the same hub were tested.

* Publication No. 104 of the Netherlands Marine Engineering Research Station, Wageningen.

† For further details, see : *Resistance and propulsion of ships* (Weerstand en voortstuwing van schepen), by W. P. A. VAN LAMMEREN, L. TROOST and J. G. KONING, publ. by H. Stam Boekhandel.

**Published papers : W. P. A. VAN LAMMEREN : *Schip en Werf*, Nos. 10 & 11, 1948.—J. BALHAN : *Schip en Werf*, Nos. 9, 10 & 11, 1948 ; *De Ingenieur*, No. 17, 1949.—J. D. VAN MANEN : *De Ingenieur*, No. 23, 1949.

‡ J. BALHAN and J. D. VAN MANEN : *Schip en Werf*, Nos. 2, 3 & 4, 1950.

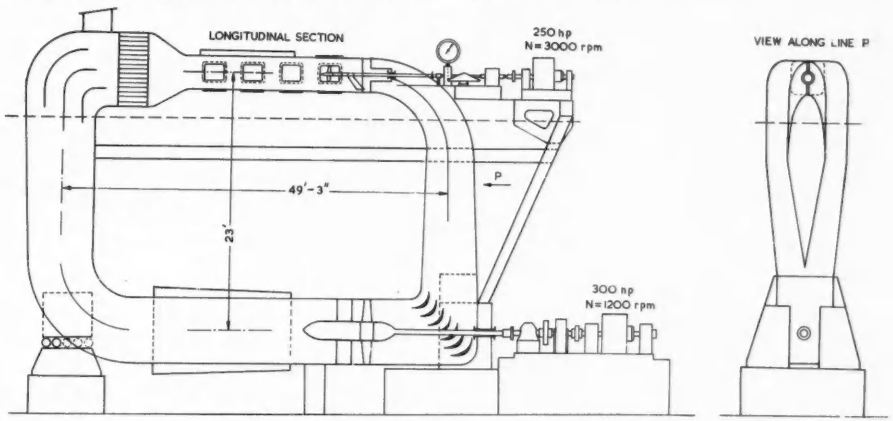


Fig. 2. **Cavitation tunnel of the Netherlands Marine Engineering Research Station.**

No signs of cavitation were found on the blades designed on the basis of the vortex theory previously mentioned. However, these tests in the cavitation tunnel were made in a homogeneous velocity field, whereas behind a ship a non-homogeneous field exists. It is possible to adapt blades to a radially non-uniform field, but not to peripheral non-uniformity. In a field of the latter type, the blade elements are situated in a flow with a periodically varying angle of incidence α_i, the variation depending on the centre angle φ, as exemplified by the values in the following table :—

$\varphi =$	0°	12°	20°	30°	60°	80°	90°	120°	140°	160°
$\alpha_i =$	+2·4°	0°	−0·8°	−0·9°	−0·9°	−0·85°	−0·8°	+0·6°	+2·2°	+4·2°

No profile can be subjected to such a variation without developing cavitation at some position, and it might then be asked whether there is any point in designing cavitation-free propellers for homogeneous fields. However, the above table shows that there is a region of the propeller disc over which α_i is fairly constant, so that, if blades are adapted for this angle of incidence, they will have no cavitation in this disc sector. As long as cavitation-erosion problems occurring at a ship's stern are not fully solved, it will be profitable to design propellers which have no cavitation in a homogeneous field, since these will be less exposed to cavitation effects during their rotation than propellers with cavitation occurring over the entire disc surface.

THREE TYPES OF CAVITATION

At present, it is possible to distinguish between three different types of cavitation, viz., *laminar*, *burbling* and *cloud* cavitation. Until recently, cloud cavitation was regarded as a particular form of burbling cavitation.

As previously stated, cavitation, i.e., the formation of vapour-filled pockets in the liquid, occurs particularly at the blade tip, where the peripheral velocity is highest. The tip cross-sections are usually very thin, with s/l ratios (thickness/length ratios) of 0·03-0·05. For these cross-sections we use profiles with a shock-free entry, that is, a stagnation point at the leading edge, and a pressure distribution as constant as possible on the suction side, without a negative pressure peak.

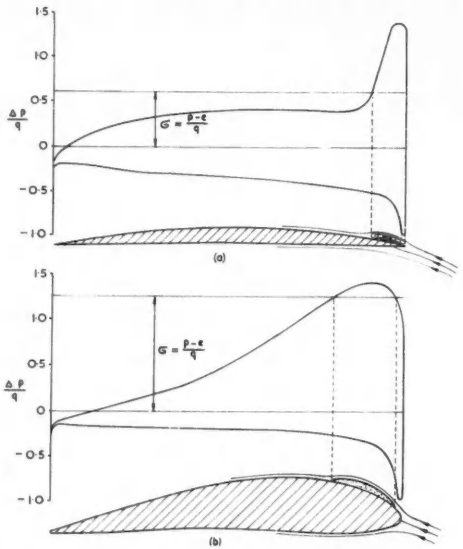


Fig. 3. **Pressure distribution of aerofoils with sharp and well rounded leading edges.**

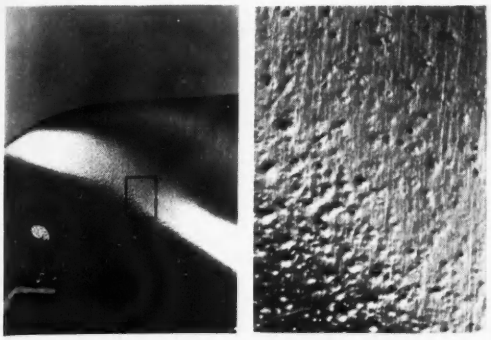
Owing to their small s/l ratio, these profiles have a fairly sharp leading edge. During the propeller rotation, the angle of incidence varies, so that shock-free entry is not maintained, and the stagnation point drops then to a position on the pressure side (see Fig. 3a).

With a fairly sharp contour, the velocity on the suction side immediately behind the leading edge becomes very high and the pressure decreases considerably. The fluid breaks away at this position and forms a vortex as a result of viscosity effects. As the vortex core, where pressure is minimum, is not at a position on the blade surface, it is not very likely that this type of vortex will be the cause of erosion. The vortex core is filled with vapour, but it is separated from the blade surface by a thin layer of liquid. This type of cavitation is known as laminar cavitation.

Fig. 4. **Cloud cavitation on a propeller in the cavitation tunnel.**

If the leading edge has a rounded contour (Fig. 3b), the flow will remain along the contour, instead of breaking away when the stagnation point and the leading edge do not coincide. A liquid particle of mass Δm, moving with a velocity c along a circular path of radius R, will remain on this path only if the pressure gradient in the normal direction $\partial p/\partial n$ is at least equal to the centrifugal force $(w/g)\, c^2/R$. Hence, this gradient is inversely proportional to the radius. For aerofoil type sections with a blunt leading edge, the value of R is large, so that the liquid can provide enough pressure to avoid a breaking away of the flow. The blunt nose section, however, even under shock-free conditions, has the effect of increasing velocity and reducing the pressure on the suction side behind the leading edge, so that cavitation may again occur. However, the conditions differ from those previously considered for sharp sections, since in this instance the minimum-pressure positions are situated right on the blade surface. Bubble formation occurs and the bubbles are not stationary but burst close to the blade surface, so that it is possible that they may cause destruction of the blade material. This type of cavitation is known as burbling cavitation.

Cloud cavitation was only recently distinguished as a separate type of cavitation. As shown in Fig. 4, it consists of hardly discernible small bubbles in a compact cluster which gives them a cloud-like appearance. Hitherto it was considered that burbling cavitation with fairly large bubbles was the cause of erosion and that the danger of erosion increases with large-size bubbles.



Full size Magnification × 10

Fig. 5. **Erosion photograph of blade 1 of propeller No. 1056 in the cavitation tunnel.**

To investigate this theory, a bronze propeller was covered with a material having a low erosion resistance and was rotated continuously in the cavitation tunnel for several days. At the end of this test, no trace was found of cavitation erosion on the blades. Repeated attempts were made to obtain erosion by means of ordinary burbling cavitation, but none gave the desired result. During a tunnel test with a non-uniform velocity field (produced by means of a board with strips of gauze-type netting), cloud-like cavitation phenomena were observed on the propeller, and after some time there was clear evidence of erosion (Fig. 5). The cloud cavitation is not stationary, so that photographs cannot be taken with normal exposures. Having found the conditions under which cloud cavitation is generated, erosion can now be produced in the cavitation tunnel in a period of a few days or even a few hours.

THEORETICAL CONSIDERATIONS ON CAVITATION-EROSION

Theories of cavitation-erosion have been formulated by various investigators, and particularly by van Iterson, Poulter, and Marboe. Moreover, mention should be made of the tests carried out by Knapp and Hollander.

Van Iterson* attributes the occurrence of erosion to the collapse or "implosion" of the bubbles on the material. The energy accumulated through surface tension on the bubble surface (this energy is proportional to the surface area) is discharged during rupture of the bubble upon a small random surface-element of the adjacent object. The pressure on this small area is sufficiently high to break off some of the molecules of the material. Assuming any constant value for the total volume of the bubbles, their total surface area (and hence their surface energy) will be greatest when this total volume is subdivided among a large number of microscopically small bubbles. Thus, maximum damage to material will occur with cloud cavitation.

The force of impact is due, then, to the surface energy of the bubbles and not to the rise in pressure occurring at the end of the cavitation zone. If the latter were the case, erosion would occur only in the corresponding region, whereas in fact it covers the entire cavitation zone. Van Iterson calculated, furthermore, the time required for the implosion of small bubbles and found it to be proportional to $r^{3/2}$, where r is the bubble radius. Thus, a small bubble of 0·05 mm radius has an implosion time of 25·4 microseconds.

Knapp and Hollander,† using a high-speed motion camera capable of taking 20,000 photographs per second, recorded the generation, impact and re-forming of bubbles on the surface of a body of revolution. From the number of frames per second of the camera, it follows that the smallest bubbles thus photographed were larger than those which we consider in cloud cavitation. In fact, these bubbles had an average diameter of 7 mm. Knapp and Hollander found that after the first impact the bubbles reappear 3 to 5 times before their last impact and final disappearance. This is in agreement with van Iterson's considerations and further explains why erosion occurs over the entire surface. The investigators also concluded that bubble size is a decisive factor as regards erosion. The fact that erosion is greater with small bubbles than with large ones has been confirmed by us in recent cavitation-tunnel experiments.

In view of the agreement, or at least the lack of contradiction, between the theories and observations of van Iterson, Knapp and Hollander, and our own investigations, we consider that erosion is mainly a result of bubble impact and therefore a purely mechanical phenomenon.

This does not, however, exclude the possibility of other contributory causes. Thus, Poulter‡ assumes that cavitation-erosion is the result of the penetration of liquid or gas in the metal from which it is subsequently liberated, this process bringing about the removal of metal particles.

Atomic hydrogen penetrates solid bodies much more rapidly than molecular hydrogen. For example, if a small, thick-walled spherical steel vessel, connected to a pressure gauge, is immersed in a liquid at atmospheric pressure, then some of the atomic hydrogen liberated at the metal surface will penetrate the steel and reach the inner surface of the sphere, where it is converted into molecular hydrogen. Owing to the different rates of diffusion of atomic and molecular hydrogen, a pressure will build up in the sphere to very high values.

Accordingly, every small closed cavity beneath the metal surface may accumulate molecular hydrogen. Below 7000 atmospheres, the rate of diffusion of molecular hydrogen in steel is slow, but it increases very rapidly above 8500 atm, so that the pressure created in such cavities is of the order of 7000 atm. After disruption occurs, the steel surrounding the cavities is a brittle material.

Another possibility considered by Poulter is the action of a liquid penetrating, and receding from, the pores in the surface of a metal. Tests have shown a direct correlation between the extent of porosity and the erosion of a metal immersed in a liquid which is subjected to a fluctuating pressure. Tungsten carbide, for instance, a very hard but porous material, can be eroded by cavitation action. If the erosion were due to a fatiguing of the metal surface by periodic forces, then mercury, owing to its higher density, should show more marked effects than water. However, the contrary has been found to be the case. Nevertheless, the fact remains that cavitation erosion can be produced by pulsating action of a liquid, as has been shown, for example, by tests with metal specimens vibrated in water at a fairly high frequency of 8000 cps. In these tests, considerable turbulence was generated as a result of the vibration, and the cavitation erosion was very noticeable.

A direct conclusion from Poulter's theory, in regard to ships' propellers, is that a non-porous surface is even more important than the hardness of the material, from the point of view of cavitation erosion. In this connection, it was pointed out by van Lammeren** that it is important to leave the skin of a casting as intact as

* F. K. T. VAN ITERSON: *De Ingenieur*, No. 19, 1940, p. W15.

† R. T. KNAPP and A. HOLLANDER: *A.S.M.E. Trans.*, Vol. 70, 1948.

‡ T. G. POULTER: *The mechanism of cavitation erosion.* Armour Research Foundation of Illinois Institute of Technology.

**W. P. A. VAN LAMMEREN: *T.N.O. Nieuws*, No. 2, 1948.

possible. This conflicts, however, with the requirements for obtaining a smooth surface and machining to the correct size. Van Lammeren suggests that it is preferable to allow a slight variation in speed instead of damaging the outer skin of the casting.

The main point in Poulter's theory is, therefore, that there is a relation between the possibility that a gas or liquid has to penetrate a metal and the extent of erosion occurring, or, at least, a relation between the extent of erosion and the porosity of the material. It is conceivable that the phenomena considered by Poulter and those previously indicated by van Iterson are both contributory to erosion.

Marboe,* among other investigators, also considers chemical effects. According to Marboe's theory, when the propeller is operating under cavitation conditions, in the spaces filled with water vapour the H_2O molecules are split into H- and O-atoms. The propeller is thus in the midst of a vortex separating positive H-ions and negative OH-ions, that is, it is exposed simultaneously to a strong acid and a strong base. If this inference is correct, it is not surprising that a combined attack of this kind should result in considerable corrosion.

TESTS IN THE CAVITATION TUNNEL

The first object of these tests was to determine the profiles which can cope with the largest possible variation in angle of incidence without cavitation. It was observed that profiles with a pressure distribution as constant as possible on the suction side can stand a somewhat greater angle of incidence than the Karman-Trefftz circular-arc type profiles hitherto used. Profiles of this latter type have been investigated by Walchner, who found that a wider range of angles of incidence could be obtained by using rounder nose-sections.

A further series of tests was arranged to assess the effectiveness of these profiles in velocity fields similar to those occurring behind a ship. A preliminary study of the velocity field behind a model of a twin-screw ship was made with Pitot tubes. The pattern obtained is shown in Fig. 6. In this figure, the numerical values indicate the wake coefficient as a percentage value, i.e., $\psi = 100\,(V_s - v_e)/V$, where V = ship speed, and v_e = entry velocity of the water on the propeller. A somewhat similar field was obtained in the cavitation tunnel by erecting in it a board with transverse pegs on either side supporting vertical strips of gauze netting. Although the gauze and netting produced appreciable turbulence, more so than occurs at a ship's stern, the velocity field was considered adequate for the tests.

During these tests, it was found that erosion was noticeable on the rear side of the propeller blades, after a few hours' rotation. As erosion on these surfaces had never occurred previously in the cavitation tunnel, it was attributed to the very turbulent flow ahead of the propeller. The phenomena of cloud cavitation were particularly apparent in these tests, and it may be surmised that if they developed to the same extent behind a ship, any propeller would be eroded within a few hours. It was thus considered that the velocity field in the cavitation tunnel was not sufficiently similar to that occurring at the stern of a ship.

To reduce the turbulence, the pegs were removed from the board and a strip of gauze netting was placed vertically on the back surface of the board. The resultant velocity distribution, shown in Fig. 7, is much more similar than previously to the pattern occurring behind a ship. In Fig. 6, the ratio $v_{e\max}/v_{e\min} = (1 - \psi_{\min})/(1 - \psi_{\max}) = (1-0{\cdot}05)/(1 - 0{\cdot}60) = 2{\cdot}37$, whereas the corresponding ratio for Fig. 7 is $1{\cdot}2/0{\cdot}6 = 2{\cdot}0$, so that the agreement between the two fields is fairly satisfactory.

Tests were then carried out with the same three-bladed propeller No. 1199 as in previous tests, i.e., a propeller with different blade designs, blade 2 consisting of Walchner profiles and blade 3 of Karman-Trefftz profiles. Photographs showed that both these blades operated without cavitation over the same disc sector, probably owing to the rapid variation of the angle of incidence from maximum to minimum values in the cavitation tunnel. At the stern of a ship, the variation is slower and the Walchner profile should give cavitation-free conditions over a wider range, extending over approximately $2 \times 15 = 30$ degrees. The expected advantages of the Karman-Trefftz profiles, on the other hand, which were the only ones supposed to produce sheet cavitation owing to their shock-free entry conditions, were not substantiated, since laminar cavitation was also obtained with the Walchner profiles, possibly owing to the rapid variation of the angle of incidence. Further observations were made on a three-bladed propeller No. 1056, with about the same features as propeller No. 1199 previously used. It was found that cloud cavitation occurred along blade 1, when it was in a horizontal position, i.e., perpendicular to the board with the gauze netting. Blades 2 and 3 showed only burbling cavitation. After three days' running, blade 1 showed some signs of erosion, whereas no erosion was apparent on blades 2 and 3. It thus seems that cloud cavitation close to the metal surface is responsible for erosion, and that burbling cavitation acts against this effect by dispersing cloud formations from the blade surface.

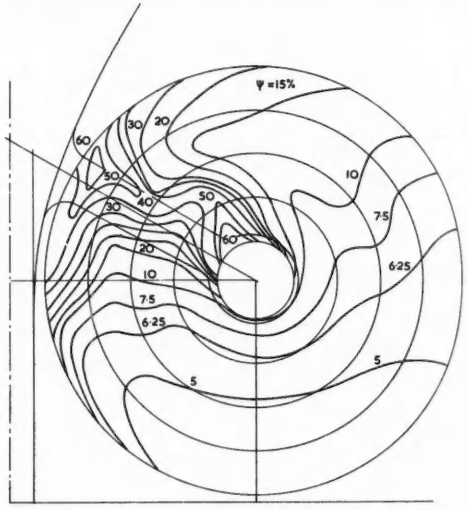


Fig. 6. **Velocity [distribution behind a twin screw ship**

Rudder erosion was also investigated. Although the rudder is situated in a region of homogeneous flow, it was considered possible that erosion might be due to cavitation generated by the propeller and thrown off in the direction of the rudder. To investigate this, tunnel tests were carried out with a copper-covered wooden rudder and a solid bronze rudder mounted behind a propeller. Tests were made with and without flow disturbance caused by the gauze-covered board ahead of the propeller and in all cases considerable erosion occurred on the rudder after a few hours' operation. Erosion on the rudder appeared over the region near the top of the propeller blade in its upright position down to about 0·7 of the propeller radius. In this region, there is a change in circulation close to the vessel, and this is coupled with rapidly produced

* E. C. MARBOE: Gas evolution from supersaturated liquids. The Pennsylvania State College, *Chemical and Engineering News*, Vol. 27, No. 31, 1949.

vortices from the blade trailing edge. Although generally barely noticeable, these vortices were clearly apparent in the tests ; therefore, rudder erosion can also be attributed to cloud cavitation.

Further tests of various propellers were made under different operating conditions. Cloud cavitation was easily produced on the pressure side of the blades and erosion was obtained even in a homogeneous velocity field in the cavitation tunnel after a few days' operation. It was also possible to obtain cloud cavitation on the rear side of the blades, but without erosion effects, since the cavitation is directed in this case away from the blade.

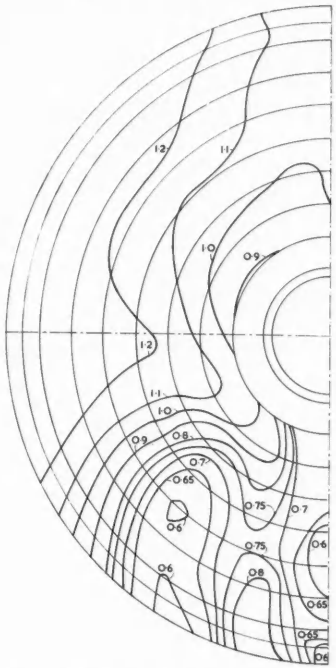


Fig. 7. **Velocity distribution behind a gauze-covered board used to obtain a non-uniform velocity field.**

The wear of propellers and rudders is frequently attributed to electrolytic action. However, in view of the short time required for erosion to occur as a result of cloud cavitation, it may well be that this wear takes place during the manoeuvring of a ship, when negative angles of incidence are obtained, with the corresponding possibility of cloud cavitation. All propellers are subjected to cavitation, but not all show erosion effects. Thus, it is possible that burbling cavitation, like laminar cavitation, is not a cause of erosion. Tunnel tests with a lead-covered propeller (lead is particularly susceptible to cavitation erosion) showed no erosion effects after several days' operation under burbling cavitation conditions.

REDUCTION OF CLOUD CAVITATION

The next problem is to look for the profiles which produce little or no cloud cavitation. To begin with, it will be assumed that those profile ratios and shapes which create cavitation are also capable of producing cloud cavitation. Considering again propeller No. 1056, tested in a non-homogeneous field, we find that blade 1, with the smallest s/l (thickness-to-length) ratios, showed considerable cloud cavitation, whereas the other two blades produced burbling cavitation. Therefore, we may infer that, with blades having large s/l ratios, cloud cavitation is driven away by burbling cavitation.

A thin profile with a sharp leading edge, under non-shock-free conditions, such as those occurring at the stern of a ship, has a marked negative pressure on the suction side of its leading edge. This gives rise to a break-away vortex, with a vortex core and laminar cavitation producing no direct erosion, at a certain distance from the blade surface. However, further downstream the phenomena developing from this laminar cavitation always have a cloud-like appearance. A plausible explanation is that as the break-away vortex rotates at a high speed, owing to the steep pressure gradient behind the negative-pressure region, it throws off a quantity of minute vapour-filled bubbles, which are carried away by the flow, with considerable danger of ercsion as a result.

A thick profile with a non-shock-free entry also has a negative-pressure peak on the suction side of its leading edge. This peak, however, is less marked than in the previous case, so that the flow will not break away. On reaching a sufficiently high vacuum, burbling cavitation is generated, and this is not so readily converted into cloud cavitation, as far as can be judged from the results now available. In a non-homogeneous field (test of propeller No. 1056 behind a board causing flow disturbance), cloud cavitation is also obtainable with this profile.

Experimental evidence of the correctness of these considerations was obtained by tunnel tests of a four-bladed propeller in a non-homogeneous velocity field. This propeller No. 611 had the following blades : Blade 1, a standard design with thin Karman-Trefftz profiles at the blade tip ; blade 3, with thin Walchner type profiles at the tip ; and blades 2 and 4, with similar contours and velocity patterns but with thicker profiles (s/l = 0·15 at 0·95R). After six hours' operation, erosion due to cloud cavitation was found on blades 1 and 3, whereas blades 2 and 4, which had shown only burbling cavitation, were free from erosion effects. Cloud cavitation on blades 1 and 3, and burbling cavitation on blades 2 and 4, were also observed with various values for the angle of incidence.

From the above tests, it may be concluded that there is considerably less possibility of cloud cavitation and ensuing erosion with thick profiles which do not show a high negative-pressure peak under non-shock-free conditions, than with the thin profiles hitherto used for the blade tip. With thin profiles, the profile shape does not appreciably alter this result.

Obviously, further tests of blade profiles with various thickness ratios, cambers and contours will be required to determine the pressure distributions which are responsible for cloud cavitation on the blade surface. The measuring section of the cavitation tunnel is now being modified to take profiles extending from one wall to the other in order to approximate two-dimensional flow conditions. In addition, full-scale tests of propellers fitted to ships would be desirable, and the co-operation of shipowners would be required for this purpose.

RAPID CAVITATION-EROSION TESTS BY MAGNETOSTRICTIVE METHOD

Under the control of a special Cavitation Erosion Committee, a large number of material specimens has been subjected to rapid cavitation-erosion tests. The specimens immersed in a liquid are fixed at one end to a hollow nickel rod which is vibrated by magnetostrictive excitation. Various bronze materials, some of which are covered with synthetic resins, plastic or rubber coatings, have been tested. The lowest losses in weight were obtained with aluminium bronzes, consisting of 81·5 per cent

(*Concluded on page* 170)

SWEDEN

Voltage Stability of a Synchronous Alternator with Capacitive Loading

By E. VOIPIO. (From *ASEA Journal*, Vol. 25, No. 11-12, November-December, 1952, pp. 138-145, 11 illustrations.)

A LARGE capacitive load can cause disturbances in the voltage of a synchronous alternator. The capacitive current has the effect of magnetising the alternator and may cause self-excitation, resulting in a prohibitively high voltage which is limited only by magnetic saturation. This instability is apt to occur on long transmission lines or may be due to erroneous capacitor batteries connections.

Voltage stability and regulation of a synchronous alternator depend mainly on the reflection of the load in the field circuit. Any transient will cause changes in the rotor flux (the total flux linking the field winding), which in turn will affect the field circuit and the flux in the alternator.

The voltage equation of the field circuit is

$$d\Phi_f/dt + R_f I_f = U_f \quad .. \quad .. \quad (1)$$

where Φ_f = rotor flux, I_f = field current, R_f = resistance of the field winding, and U_f = exciter voltage. I_f and Φ_f can be expressed by means of voltages in the equations for the stator circuit, i.e., by means of the relations

$$E = G R_f I_f \quad \text{and} \quad .. \quad .. \quad .. \quad (2)$$

$$E' = G R_f \Phi_f / L_f = G \Phi_f / T_{do}' \quad .. \quad (3)$$

where E = synchronous emf, E' = transient emf, G = voltage amplification of alternator on open circuit, L_f = inductance of field winding, and T_{do}' = open-circuit time constant of alternator. On open circuit, both E and E' are equal to the alternator voltage U; but when a load is applied, these three voltages diverge, and the manner in which this occurs is important in voltage regulation.

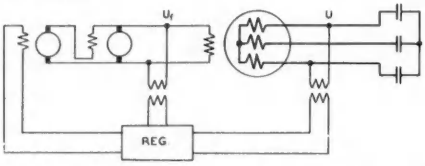


Fig. 1. **Synchronous alternator with capacitive loading.**

With a capacitive loading in a circuit such as that of Fig. 1, the alternator becomes magnetised. The voltage drop across the stator circuit reactance is in such a direction as to cause a voltage rise in relation to the open-circuit voltage.

For steady-state conditions, the alternator voltage is obtained from

$$\mathbf{U} = \mathbf{E} - j X_d \mathbf{I}_{cd} - j X_q \mathbf{I}_{cq} - R_a \mathbf{I}_c \quad .. \quad (4)$$

where I_{cd}, I_{cq} = direct and quadrature components, respectively, X_d, X_q = corresponding reactances, I_c = capacitive load current, R_a = stator circuit resistance, and j = phase advance of 90 deg. (Complex quantities are indicated in bold type). For fairly light loads, R_a may be disregarded, and the voltage equation is then, approximately,

$$U \sim E + X_d I_c \quad .. \quad .. \quad (5)$$

The voltage across the load capacitor is equal to the alternator voltage. If $X_c = 1/(\omega C)$ is the capacitive reactance, we have $\mathbf{U} = -j X_c \mathbf{I}_c$, so that

$$U = X_c I_c \quad .. \quad .. \quad (6)$$

For rapid transients occurring without a change in the rotor flux, the voltage depends on E' and the transient reactance X_d'. The latter applies only to the direct component of the current, since the field winding acts in the direction of the poles. For example, if a capacitive load is connected to an unloaded alternator, E' will equal E and the fundamental voltage component is $\mathbf{U} = \mathbf{E} - j X_d' \mathbf{I}_{cd} - j X_q \mathbf{I}_{cq} - R_a \mathbf{I}_c$, or approximately,

$$U \sim E + X_d' I_c \quad .. \quad .. \quad (7)$$

If there is no regulator, the voltage will vary, as indicated by eqs. (5), (6) and (7) from

$$U \sim X_c E/(X_c - X_d) \text{ to } U \sim X_c E/(X_c - X_d') \quad (8a; 8b)$$

To reduce the alternator voltage to its original value, it is necessary to reduce the excitation current. Hence E and Φ_f are affected. The value of Φ_f also depends on the load current. Thus, in re-establishing the steady-state conditions, a change takes place in the rotor flux, which is proportional to the voltage drop due to the difference between the synchronous and transient values of reactance. Therefore, the transient emf is

$$\mathbf{E}' = \mathbf{E} - j (X_d - X_d') \mathbf{I}_{cd}, \text{ or approximately,}$$

$$E' \sim E + (X_d - X_d') I_c \quad .. \quad (9)$$

A simple graphical construction is shown in Fig. 2. The procedure is as follows: (i) draw U and the resistive voltage drop $R_a I_c$; (ii) from this point, draw $X_d' I_c$, $X_q I_c$ and $X_d I_c$, calculating these on the basis of the total current; (iii) draw the quadrature direction ("q-axis") through the end of $X_q I_c$; and (iv) determine E and E' by projecting the ends of $X_d I_c$ and $X_d' I_c$ in this direction. The diagram shows that the capacitive load is so large that a negative excitation is required. Frequently, the contribution of R_a is neglected. This would imply that the "internal load angle" δ between E and U is negligible. The diagram, however, shows that a large increase in load will cause an appreciable increase of δ.

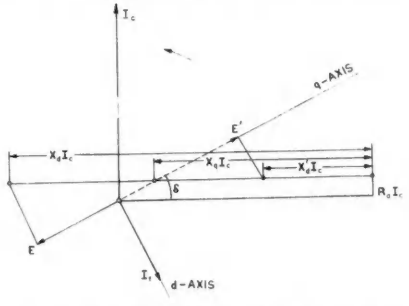


Fig. 2. **Graphical determination of the synchronous e.m.f. E and the transient e.m.f. E'.**

The expressions for the synchronous and transient e.m.f.'s, E and E', are obtained from the vector diagram as

$$E = U [R_a^2 + A B] \Big/ \left\{ [X_c \sqrt{R_a^2 + B^2}] \right\} \quad .. \quad (10a)$$

and

$$E' = U [R_a^2 + A' B] \Big/ \left\{ X_c \sqrt{R_a^2 + B^2} \right\} \quad .. \quad (10b)$$

where

$A = X_c - X_d$, $B = X_c - X_q$, and $A' = X_c - X_d'$.

The angle δ is

$$\delta = \tan^{-1} \left\{ [R_a/B] \right\} \quad .. \quad (10c)$$

Fig. 3 shows the loci of E and E' obtained by continuously increasing the load and keeping the voltage

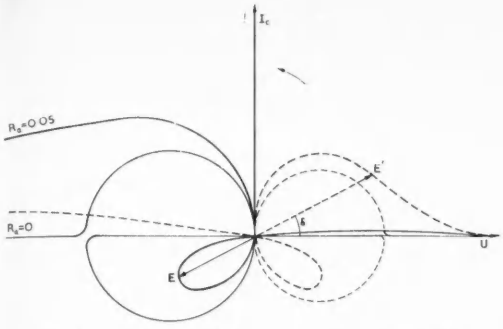


Fig. 3. **Locus diagram of the synchronous e.m.f. E and the transient e.m.f. E'.**

constant by simultaneous adjustment of the excitation. Inside the loop, both e.m.f. values are negative. Fig. 4 gives E and E' as functions of the relative capacitive loading, $Q_c = U^2/X_c$. From the point of view of stability, this figure can be divided into four regions :

I :	$X_c > X_d$	$I_f > 0$	$\Phi_f > 0$	$\delta = 0$
II :	$X_d > X_c > X_q$	$I_f < 0$	$\Phi_f > 0$	$0 < \delta < 90$
III :	$X_q > X_c > X_d'$	$I_f > 0$	$\Phi_f < 0$	$90 < \delta < 180$
IV :	$X_d' > X_c$	$I_f > 0$	$\Phi_f > 0$	$\delta \sim 180 - \tan^{-1} R_a/X_q$

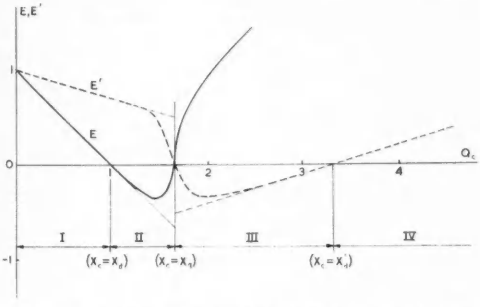


Fig. 4. **Synchronous e.m.f. E and transient e.m.f. E' as functions of the relative capacitive loading Q_c.**

The excitation required is zero at two points (" direct " and " quadrature " resonance), corresponding approximately to $X_c = X_d$ and $X_c = X_q$.

SELF-EXCITATION AND VOLTAGE STABILITY

When additional loads are connected, the transients consist of several components. Considering only the predominating transient with the longest duration, we can express it by means of an exponential-decay type of equation :

$$U - U_\infty = (U_0 - U_\infty) \exp(-t/T_f') \quad .. \quad (11)$$

where U_∞ = steady value of final voltage, $U_0 - U_\infty$ = original deviation, and T_f' = time constant obtained from the equation of the loaded machine. If the complete equation is used, the expression for T_f' is fairly complicated. A simpler approximation is obtained by assuming that the transient is slow compared with the synchronous frequency. This gives the differential equation

$$T_{d0}' \frac{dE'}{dt} + E = G U_f \quad .. \quad (12)$$

Stability depends on the corresponding homogeneous equation. Assuming that current and flux are mutually proportional, we have

$$(E_\infty'/E_\infty)\, T_{d0}'\, (dE'/dt) + E' = 0.$$

As the attenuation of the emf values and the voltages is due to the same physical processes, this equation gives the common time constant, with $E' - E_\infty' = (E_0' - E_\infty') \exp(-t/T_f')$, and therefore

$$T_f' = (E_\infty'/E_\infty)\, T_{d0}' = \Phi_f/(R_f I_f) \quad .. \quad (13)$$

Equation (12) for the stator circuit is of the same form as eq. (1) which refers to the field circuit. T_f' is the resultant time constant in the field circuit.

The above equations, assuming a slow change, disregard " d.c. components " in the stator circuit, as well as currents induced in the damper winding and the eddy-current circuits. As a result of a more detailed analysis, it may be said that eq. (13) is a good approximation within the regions I and II of Fig. 4. It is less accurate for region III, but gives a correct indication regarding stability. In region IV, greater accuracy is again obtained with this expression.

With a high capacitive loading, instead of being positive the time constant T_f' may assume negative values, and the voltage then becomes unstable. T_f' becomes negative if either I_f or Φ_f is positive while the other is negative. These two cases have different effects on the voltage regulation. The two naturally unstable regions are II and III (in II : $E < 0$ and hence $I_f < 0$, whereas in III : $E' < 0$ and hence $\Phi_f < 0$). The risk of voltage instability is reduced by increasing the stator resistance R_a. In an $R_a - X_c$ diagram, the unstable regions are practically covered by two semicircles, extending from X_d' to X_q (for $E' < 0$) and from X_q to X_d (for $E < 0$), in accordance with eqs. (10a) and (10b).

STABILITY WITH AUTOMATIC REGULATION

To increase the permissible capacitive loading beyond the natural limit of stability (I in Fig. 4), the regulator must be capable of feeding the alternator with negative excitation current. At the same time, regulation stability must be assured, without deterioration of regulating properties at normal loads.

The ASEA high-speed regulating systems, operating either with a contact-type regulator or a transductor, provide this negative excitation and are also extensively adaptable to different requirements of alternators under load. The regulation equation, obtained from eq. (12) by multiplying by the ratio of the voltage and the synchronous e.m.f., is

$$T_f' \, dU/dt + U = K U_f$$

This determines the alternator voltage response to regulating action in the rotor circuit. Thus, if the exciter voltage is altered by an increment ΔU_f, the change in alternator voltage is

$$\Delta U = K \Delta U_f [1 - \exp(-t/T_f')] \quad .. \quad (14)$$

The curves for various loads, obtained from eq. (14), are shown in Fig. 5. With increased demands on rapidity of regulation, the stability of automatic voltage regulation becomes more critical. Even on open circuit or with small capacitive loads, it is then necessary to match the amplification and damping in the regulator to the properties of the main machine.

Stable regulation presents no serious difficulties either in region I or in region II of Fig. 4, although in the latter region the risk of over-regulation is somewhat greater. In cases where the margin of safety is not sufficient, the necessary damping can be obtained by altering the feedback. In region III, the voltage regulation is in the wrong direction, so that, with normal regulation methods, stable regulation is not attainable.

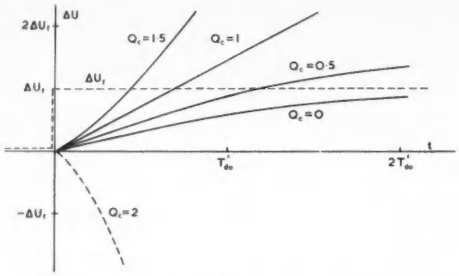


Fig. 5. **Regulating action ΔU in alternator voltage after a unit-step change ΔU_f in exciter voltage.**

The main effect of automatic regulation is that the voltage is stable even with negative excitation. The stability limit is displaced from $X_c = X_d$ to close to the point of quadrature resonance ($X_c = X_q$). This constitutes a useful margin of stability, which applies, however, only to salient-pole machines. For turbo-alternators, in which $X_q = X_d$, there is no region of loading with negative excitation, and the corresponding increase in stability disappears.

MAGNETIC SATURATION

The above equations are approximate only, owing to magnetic saturation in the alternator. The curves of excitation current I_f, plotted for constant voltages against Q_c, decrease linearly at first down to negative values and then rise nearly vertically. The points of direct and quadrature resonance, Q_{c1} and Q_{c2}, at which these curves intersect the Q_c line, are shifted by the voltage. As the synchronous resonance is approximately equal to the capacitive reactance at resonance, we may write

$$X_d = 1/Q_{c1} \quad \text{and} \quad X_q = 1/Q_{c2}.$$

The relation between the capacitive reactance and the reactance of the alternator determines the stability limit. However, the reactances of synchronous machines may be interpreted in different ways. Fig. 6 shows the excitation curve of an alternator. This is similar to the curve of the air-gap voltage E_l as a function of the resultant mmf I_d. The reactance can be defined in the following three ways :—

$$X_d = X_l + (E_{l0}/\Sigma I_d), \qquad X_d = X_l + (E_l/\Sigma I_d),$$

and

$$X_d = X_l + (d E_l/d \Sigma I_d),$$

where X_l = leakage reactance of the stator circuit, E_l = actual air-gap voltage, and E_{l0} = air-gap voltage from air-gap characteristic. Corresponding expressions can be written for X_q.

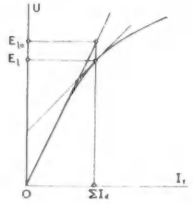


Fig. 6. **Determination of reactances in a saturated alternator.**

For steady-state conditions, the I_f — Q_c curves previously mentioned are calculated from the equation $X_d = X_l + (E_l/\Sigma I_d)$, and the regions of loading are determined by analogy with Fig. 4. If an approximate relation is sufficient, the analogy may be extended to the stability considerations. Owing to the changes in the stationary reactances during transients, the actual conditions governing stability are more complicated. This is evident from the loading curves (see Fig. 7).

The conditions may be approximately assessed by means of the Potier triangle. However, if the loading is so high that saturation in the quadrature direction must be taken into account, an abnormal form of curve is obtained. Under unsaturated conditions, $X_c < X_q$, and the excitation current I_f is positive. With increasing voltage, I_f passes through Q_{c2} and Q_{c1} before finally becoming positive again.

Stable conditions occur as long as the loading curve lies to the right of the vertical axis. If U_t is fixed, the voltage will follow the upper portion of the curve. If $U_f = 0$, the point A, at which the voltage is stable, is obtained.

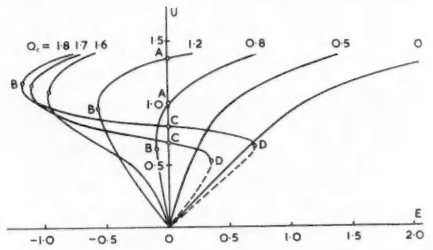


Fig. 7. **Experimental loading curves for constant load capacitance.**

The equation for the rotor circuit gives further information on stability. For saturated machines, eq. (12) is not linear, but can be linearised by considering only the region immediately adjacent to the point of loading. The voltage is stable as long as $\partial U/\partial E > 0$, even from A to B in Fig. 7, and this is confirmed in practice. With automatic regulation, stable voltage may also be obtained over the portion B C, for which $I_f < 0$. If eq. (12) is fully applicable, stability is ensured as far as point D. However, as the alternator is already in quadrature resonance at C, the damper circuits will function and the voltage is stable only special cases.

Therefore, to avoid any risk of unstable voltages, complete stability must exist when the machine is unsaturated. With saturation, improved stability is then usually obtained at higher voltages.

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THE CAVITATION-EROSION OF SHIPS' PROPELLERS

(*Concluded from page* 167)

copper, 10·13 aluminium, 3·72 nickel, 4·55 iron and 0·10 per cent lead. The various coatings gave very good results.

CONCLUDING REMARKS

The theory of cloud cavitation was developed at the Marine Engineering Research Station, Wageningen. It is still in its initial stages. Propellers based on Wageningen designs are used by various shipowners, and these are requested to inform the Research Station of any signs of erosion occurring on such propellers, in order to collect as much experimental information as possible. The intention is to carry out repeat tests on any propeller which has been found eroded so as to ascertain whether the damage is due to burbling or cloud cavitation and to obtain data for further development work.

Pressure Pulsation at the Intake of a Supercharged Internal Combustion Engine

By L. S. Dzung. (From *Brown Boveri Review*, Vol. 39, No. 8/9, August/September, 1952, pp. 295-305, 8 illustrations.)

(*Concluded from April issue.*)

5. The Energy Flow in the Manifold Vessel

The assumption, eq. (2), of isentropic air conditions in the vessel is not quite correct. The supercharging blower delivers air continuously into the vessel. The air conditions at the vessel inlet depend upon the blower efficiency. If the inlet pressure is changed, the inlet temperature will not change isentropically with the pressure because of blower loss. Within the vessel the pressure wave propagates isentropically from inlet to outlet, but the state of the incoming air does not remain on the same isentropic. Every point on the inlet condition line produces an isentropic wave propagating towards the outlet. The condition points cover a surface element of the state diagram.

Consider an element $V\,\mathrm{d}\,x$ of the vessel volume, which is taken to be cylindrical. x is the co-ordinate variable having the value 0 at inlet and 1 at outlet. The through-flow rate is denoted by G and the specific stagnation enthalpy by h at the point x. The mass balance and energy balance for the volume element give,

$$G - (G + \mathrm{d}\,G) = (V\,\mathrm{d}\,x)\frac{\partial \rho}{\partial t},$$

$$Gh - (G + \mathrm{d}\,G)(h + \mathrm{d}\,h) = (V\,\mathrm{d}\,x)\left[\frac{\partial (\rho h)}{\partial t} - \frac{\partial p}{\partial t}\right]$$

The left-hand sides of these equations are the rates of mass and enthalpy flow into and out of the volume element. The right-hand sides are the rates of change of mass density and of enthalpy density diminished, in the second equation, by the rate of mechanical work done on the flowing air. Frictional stresses and heat conduction are neglected. The kinetic energy of flow is included in the definition of stagnation enthalpy.

For an ideal gas with constant specific heat the enthalpy can be replaced by the temperature T. Denoting $\vartheta = \Delta T/T_0$ and $\lambda = k/(k-1)$, we obtain in our dimensionless variables for small perturbations:

$$-\frac{\partial g}{\partial x} = \frac{\partial \sigma}{\partial \tau}$$

$$-\frac{\partial \vartheta}{\partial x} - \frac{\partial g}{\partial x} = \frac{\partial \sigma}{\partial \tau} + \frac{\partial \vartheta}{\partial \tau} - \frac{1}{\lambda}\frac{\partial \beta}{\partial \tau}$$

and for harmonic vibration, after the first equation is subtracted from the second:

$$i\,\Omega\,\sigma + \frac{\mathrm{d}\,g}{\mathrm{d}\,x} = 0 \quad \ldots \quad \ldots \quad (9)$$

$$i\,\Omega\,\vartheta + \frac{\mathrm{d}\,\vartheta}{\mathrm{d}\,x} = -\frac{1}{\lambda}\,i\,\Omega\,\beta \quad \ldots \quad (10)$$

The pressure wave propagates with the sonic speed a_0 relative to the air which is flowing with a velocity w_0. Neglecting the viscosity and thermal conductivity of the air, the amplitude of the pressure wave does not change in the course of propagation, although the phase varies. Corresponding to the wave length of $\Lambda = 2\pi\,(w_0 + a_0)/\omega$ we may set

$$\beta = \beta_1\,e^{-i\,2\pi x L/\Lambda}$$

where L is the total length of the vessel. β_1 is the pressure at the vessel inlet, as in Section 2, and is equal to the delivery pressure of the blower. From the definition of Ω and since $w_0\,t_0 = L$ we have

$$\beta = \beta_1\,e^{-i\,\Omega\,m x}, \quad m = M/(1+M)$$

where $M = w_0/a_0$ is the Mach number. By neglecting m compared with 1, integration of eq. (10) yields

$$\left(\frac{\beta_1}{\lambda}e^{-i\,\Omega\,m x} - \vartheta\right) = \left(\frac{\beta_1}{\lambda} - \vartheta_1\right)e^{-i\,\Omega\,x} \quad (11)$$

This equation has been derived only for the stagnation temperature. Now we shall neglect the kinetic energy of flow in the vessel. Since the flow speed is very low compared with the sonic speed, it is not necessary to distinguish between static temperature and stagnation temperature. Then we can use the stagnation temperature in the equation of state $p = \rho RT$ for ideal gas, i.e., $\beta = \sigma + \vartheta$. Eq. (9) with (11) becomes

$$\frac{\mathrm{d}\,g}{\mathrm{d}\,x} + i\Omega\left[\left(\beta_1 - \frac{\beta_1}{\lambda}\right)e^{-i\,\Omega\,m x} + \left(\frac{\beta_1}{\lambda} - \vartheta_1\right)e^{-i\,\Omega\,x}\right] = 0 \quad (12)$$

Integrating between inlet and outlet gives, with $\lambda/(\lambda-1) = k$:

$$(g_2 - g_1) + \frac{1 - e^{-i\,\Omega m}}{km}\beta_1 + \left(\frac{\beta_1}{\lambda} - \vartheta_1\right)(1 - e^{-i\,\Omega}) = 0 \quad (13)$$

The conditions at the inlet of the vessel are the same as those at the outlet of the blower, as explained before. The relation between the temperature and the pressure is given by the characteristic of the supercharging blower. We now plot the pressure coefficient of the blower $\mu' = \int v\,\mathrm{d}\,p/U^2$ against the internal power consumption coefficient $\mu_0 = N/GU^2$ (Fig. 5). U is the peripheral speed, v the specific volume. The ratio μ'/μ_0 is the usual definition of polytropic efficiency of compression. Following this concept we now define the *tangential* efficiency η_t as the slope of the characteristic $\mu'\,\mu_0$ curve at the operating point, thus:

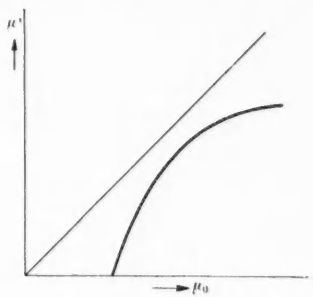


Fig. 5. **Blower characteristic.**

$$\eta_t = \frac{\mathrm{d}\,\mu'}{\mathrm{d}\,\mu_0} = \frac{v\,\mathrm{d}\,p}{\mathrm{d}\,h} = \frac{\beta_1}{\lambda\,\vartheta_1} \quad \ldots \quad \ldots \quad (14)$$

This "efficiency" can of course take any numerical value between zero (surge limit) and infinity (maximum flow). Substituting ϑ_1 from eq. (14) and g_1 from eq. (3) into eq. (13), we obtain

$$g_2 = \left\{ \frac{1}{\psi} - \frac{i\,\Omega}{k}\left(\frac{1-e^{-i\,\Omega\,m}}{i\,\Omega\,m}\right) + \frac{1-\eta_t}{\lambda\,\eta_t}(1-e^{-i\,\Omega}) \right\} \beta_1 \qquad (15)$$

This equation reduces to eq. (4) for $m = 0$ and $\eta_t = 1$. The energy balance for the piston displacement volume V' gives

$$G_2\,(u_2 + p_2/\rho_2) = \frac{\mathrm{d}}{\mathrm{d}\,t}(\rho'\,u'\,V') + p'\frac{\mathrm{d}\,V'}{\mathrm{d}\,t}$$

The left-hand side is the energy convected with the air flow. u is the stagnation internal energy. The subscript 2 refers to the condition at vessel outlet. The right-hand side is the rate of increase of the internal energy together with the work done by the piston movement. The state quantities ρ', u', p' refer to the spatial average values in cylinder volume. The dimensions of the cylinder are assumed to be small compared with the wavelength.

Following the same reasoning as in Section 4, it is seen that the last equation is valid only for the action of the suction stroke, but not for the separation and annexation of volume due to valve movement. From the quantity $G_2\,(u_2 + p_2/\rho_2) = G_2\,h_2$ we must subtract the constant term $G_0\,h_0$ as in Fig. 2. The temperature and the flow rate at inlet and outlet of the vessel must be equal in the stationary state, because there is no heat loss. Now we can apply the Fourier expansion to the small deviations about the stationary value and consider only one frequency. The last equation becomes

$$(G_2\,h_2 - G_0\,h_0) = u_0'\,V_0'\frac{\mathrm{d}\,\Delta\rho'}{\mathrm{d}\,t} + \rho_0'\,V_0'\frac{\mathrm{d}\,\Delta u'}{\mathrm{d}\,t} + (\rho_0'\,u_0' + p_0)\frac{\mathrm{d}\,\Delta V'}{\mathrm{d}\,t}$$

or in our dimensionless variables, since $h/u = c_p/c_v = k$ for ideal gases with constant specific heat.

$$\epsilon\,(g_2 + \vartheta_2) = \frac{1}{k}\left(\frac{\mathrm{d}\,\sigma'}{\mathrm{d}\,\tau} + \frac{\mathrm{d}\,\vartheta'}{\mathrm{d}\,\tau}\right) + \frac{\mathrm{d}\,v}{\mathrm{d}\,\tau}$$

ϑ_2 is the temperature at vessel outlet. Using the equation of state $\beta' = \sigma' + \vartheta'$ the above equation becomes, for harmonic vibration:

$$\epsilon\,(g_2 + \vartheta_2) = \frac{i\,\Omega\,\beta'}{k} + i\,\Omega\,v$$

The normalized reciprocal response function between β_1 and v is:

$$-\frac{k\,v}{\beta_1} = \frac{\beta'}{\beta_1} - \frac{\epsilon\,k}{i\,\Omega}\left(\frac{g_2}{\beta_1} + \frac{\vartheta_2}{\beta_1}\right) \qquad .. \quad (16)$$

Compared with eq. (7) we have here a new term with the factor ϑ_2/β_1. This is given by eq. (11) for $x = 1$ and with eq. (14)

$$\frac{\vartheta_2}{\beta_1} = \frac{1}{\lambda}\left[e^{-i\,\Omega\,m} + \frac{1-\eta_t}{\eta_t}\,e^{-i\,\Omega}\right]$$

The term β'/β_1 of eq. (16) can be obtained from eq. (5). From the derivation of eq. (5) it may be inferred that if the pressure in the vessel is not uniform, β must be understood to be the outlet pressure β_2. Instead of (5) we must therefore write

$$\frac{\beta'}{\beta_2} = 1 - i\,\Omega\,\xi\,\frac{g_2}{\beta_2}$$

or

$$\frac{\beta'}{\beta_1} = e^{-i\,\Omega\,m} - i\,\Omega\,\xi\,\frac{g_2}{\beta_1} \qquad .. \quad (17)$$

Together with eq. (15) all the terms on the right-hand side of eq. (16) are now known. Substitution gives

$$-\frac{k\,v}{\beta_1} = e^{-i\,\Omega\,m} + \left(\epsilon - \frac{\Omega^2\,\xi}{k}\right)\left(\frac{1-e^{-i\,\Omega\,m}}{i\,\Omega\,m}\right) - i\,\Omega\,\xi\left[\frac{1}{\psi} + \frac{1-\eta_t}{\lambda\,\eta_t}(1-e^{-i\,\Omega})\right] - \frac{\epsilon\,k}{i\,\Omega}\left[\frac{1}{\psi} - \frac{1-e^{-i\,\Omega\,m}}{\lambda} + \frac{1}{\lambda\,\eta_t}\right] \qquad .. \quad (18)$$

This is the reciprocal response function $1/C$ in place of eq. (8).

6. Several Manifold Outlets

Our treatment has been limited to the case where there is only one single opening connecting the vessel volume and the cylinder volume. Actually there is one connection for each cylinder of a multi-cylinder engine. It is easy to see that exactly the same equations will be obtained as before, if the distances between the connecting points can be assumed to be small compared with the vessel dimensions. Due to linear assumption we may decompose the periodic pulsation of frequency Ω/n in one cylinder of an n-cylinder engine into its Fourier series. This fundamental frequency can be taken, e.g., as half the speed of rotation of a four-stroke engine. Evidently all the previous equations are valid for each component of the series. If this is also done for the other cylinders it will be found that the vibration phases of different cylinders are mutually so shifted that the resultants of all frequencies balance out except one. The remaining non-zero resultant is the nth harmonic having the frequency Ω, whose components are all in phase. Hence the frequency response curve is exactly what we had before.

If the distances between outlet points are small but not negligible, then each cylinder will have a different response curve. Suppose x_i $(i = 1 \ldots n)$ are the coordinate variables of the outlet points in the sense of Section 5. The integration of eq. (12), taking care of eq. (3) and (14), then becomes:

$$g_{2i} = \left\{ \frac{1}{\psi} - \frac{i\,\Omega}{k} \times \frac{1-e^{-i\Omega m x_i}}{i\,\Omega\,m} + \frac{1-\eta_t}{\lambda\,\eta_t}(1-e^{-i\Omega x_i}) \right\} \beta_{1i}$$

for each cylinder instead of eq. (15). With eqs. (17) and (16) we obtain:

$$-\frac{k\,v_i}{\beta_{1i}} = e^{-i\Omega m x_i} + \left(\epsilon - \frac{\Omega^2\,\xi}{k}\right)\left(\frac{1-e^{-i\Omega m x_i}}{i\,\Omega\,m}\right) - i\,\Omega\,\xi\left[\frac{1}{\psi} + \frac{1-\eta_t}{\lambda\,\eta_t}(1-e^{-i\Omega x_i})\right] - \frac{\epsilon\,k}{i\,\Omega}\left[\frac{1}{\psi} - \frac{1-e^{-i\Omega m x_i}}{\lambda} + \frac{1}{\lambda\,\eta_t}\right]$$

Basing on the previous reasoning we shall now assume as an approximation that the pressure vibrations β_{1i} of all cylinders are equal for the n^{th} harmonic of the fundamental frequency. Then the total effect can be obtained by summing over every cylinder:

$$\frac{1}{C} = f_m\,e^{-i\Omega m\bar{x}} + \left(\epsilon + \frac{\Omega^2\,\xi}{k}\right)\left(\frac{1-f_m\,e^{-i\Omega m\bar{x}}}{i\,\Omega\,m}\right) - i\,\Omega\,\xi\left[\frac{1}{\psi} + \frac{1-\eta_t}{\lambda\,\eta_t}(1-f_1\,e^{-i\Omega\bar{x}})\right] - \frac{\epsilon\,k}{i\,\Omega}\left[\frac{1}{\psi} - \frac{1-f_m\,e^{-i\Omega m\bar{x}}}{\lambda} + \frac{1}{\lambda\,\eta_t}\right] \qquad .. \quad (19)$$

where $\bar{x} = \sum_i x_i/n$ is the mean value of the co-ordinate variables. The real factor

$$f_m = \left\{ \sum_i \exp\left[-i\,\Omega\,(x_i - \bar{x})\,m \right] \right\} / n$$

takes care of the phase shift between pressure and temperature waves. Following the conception of winding "breadth factor" in alternating-current machine practice, one easily finds the expression:

$$f_m = \frac{\sin\left(\frac{n\,m}{2}\,\Omega\,\Delta x\right)}{n \sin\left(\frac{m}{2}\,\Omega\,\Delta x\right)}$$

where $\Delta x = x_i - x_{i-1}$ is the distance between two adjacent outlet points.

The assumption that the pressure pulsations of different cylinders are equal is of course not strictly true. It is rather the excitations ν_i of different cylinders which are equal. Furthermore, other harmonics than the n^{th} will also be present, since for these harmonics only the causes of vibration balance out, not the effects. It is in principle possible to calculate the larger harmonics of the pressure wave for each cylinder from the Fourier analysis of the volume change excitation and to superimpose them under consideration of the ignition sequence.

7. The Dynamic Characteristic of the Blower

We have so far represented the characteristic of the supercharging blower by the slope ψ, eq. (3). By taking it as a real quantity independent of the frequency, it has been assumed that the air flow immediately followed the pressure change. This is true if the kinetic energy of the air contained in the blower is so small that its conversion into potential pressure energy can be accomplished in a time much shorter than the period of change. This can, however, no longer be the case at high frequency.

Suppose the static pressure/volume curve has a slope of $(\mathrm{d}\,p_1/\mathrm{d}\,G_1)_0 = S$ at the stationary operating point p_0, G_0. At this point the blower pressure and the pressure at the vessel inlet are equal. If the flow rate is changed by ΔG_1 then the pressure produced by the blower will be changed by $S\,\Delta G_1$. If now the pressure at the vessel inlet also changed by Δp_1 then the difference $S\,\Delta G_1 - \Delta p_1$ will accelerate the air contained in the blower:

$$(S\,\Delta G_1 - \Delta p_1)\,F_1 = \rho_1\,V_1\,\frac{\mathrm{d}\,w_1}{\mathrm{d}\,t} + \frac{V_1}{F_1}\,\frac{\mathrm{d}\,\Delta G_1}{\mathrm{d}\,t}$$

where w_1 is the air velocity through the blower, V_1 the volume of air in the blower, and F_1 a representative cross-section of flow. Putting $\psi_0 = SG_0/p_0$, the last equation, when written in our dimensionless form, becomes:

$$\psi_0\,g_1 - \beta_1 = \zeta\,\frac{\mathrm{d}\,g_1}{\mathrm{d}\,\tau} = \zeta\,i\,\Omega\,g_1$$

and

$$\psi = \frac{\beta_1}{g_1} = \psi_0 - i\,\Omega\,\zeta, \quad \zeta = \frac{G_0^2}{(F_1^2/V_1)\,p_0\,\rho_0\,V} \quad .. \quad (20)$$

The "time constant" ζ combines the different arbitrarily defined quantities and is to be considered as an empirical factor. The expression F_1^2/V_1 is nothing other than a kind of acoustic conductance μ, defined in Section 3. Since ψ_0 is usually negative, eq. (20) indicates that the decrease of flow rate $-g_1$ lags behind the increase of pressure β_1 and the more so the higher the frequency. At very high frequencies, g_1 vanishes for finite β_1. The flow rate can no longer follow the pressure change.

8. Existence of the Steady State

This treatment of the response function and harmonic curve applies only to a steady state after the transient has died away. We must therefore first find out whether a steady state exists at all, for it is possible that the initial disturbances may not die away, due to energy supplied by self-excitation. Consider the differential equations (1), (5) and (7). If g_2 and β' are eliminated with eq. (2), (3) and the equation of state, we obtain corresponding to eq. (8) the unabbreviated differential equation:

$$\frac{\mathrm{d}^3\beta}{\mathrm{d}\,\tau^3} - \frac{k}{\psi}\,\frac{\mathrm{d}^2\beta}{\mathrm{d}\,\tau^2} + \frac{k}{\xi}(1+\epsilon)\,\frac{\mathrm{d}\,\beta}{\mathrm{d}\,\tau} - \frac{\epsilon\,k^2}{\xi\,\psi}\,\beta = -\frac{k^2}{\xi}\,\frac{\mathrm{d}\,\nu}{\mathrm{d}\,\tau} \quad (21)$$

The right-hand side is the excitation known as a function of time, which we consider to be harmonic.

From the theory of differential equations, we know that the solution of (21) is composed of two parts, the particular integral and the complementary function. Eq. (8) is the particular integral which is caused by the presence of the forcing function. The complementary function is the solution of the homogeneous equation for free vibration, obtained by crossing out the right-hand member of eq. (21). The particular integral represents the steady state solution, but only if the transient dies away. This condition will be fulfilled for our linear differential equation with constant coefficient if all the roots of the corresponding characteristic equations

$$z^3 - \frac{k}{\psi}\,z^2 + \frac{k}{\xi}(1+\epsilon)\,z - \frac{\epsilon\,k^2}{\xi\,\psi} = 0 \quad .. \quad (22)$$

have a negative real part. Roots with positive real parts indicate possibility of self-excitation. The amplitude of the free vibration will increase with time. For this equation solely to have roots with negative real parts, it is necessary that the coefficients be all of the same sign. Since k, ξ, and ϵ are essentially positive, this means that ψ must be negative. Using the criterion of Hurwitz, it can be shown that a negative ψ is not only necessary but also sufficient for eq. (22) to have no root with a positive real part. Within the validity limits of eq. (8), the system is therefore stable as long as the supercharging blower is operating on the drooping part of its characteristic. This simple result could of course be reached also by elementary reasoning.

For the more general cases treated in Sections 5, 6, and 7, the characteristic equation of the free vibration is obtained by equating the excitation ν to zero in eq. (18) or (19) and by substituting the variable z for $i\,\Omega$. The equations $F(z) = 0$ so obtained are transcendental, for which the criterion of Hurwitz does not apply. Instead of this, one may use the graphical stability criterion method by means of the transfer function curve due to Nyquist. This entails plotting the harmonic characteristic function $F(i\,\Omega)$ for different frequencies on the complex number plane. This characteristic function is nothing other than the reciprocal response function $1/C$, i.e., the expression in eq. (18) or (19). The corresponding curve to be used as stability criterion is the plot of $1/C$. This is already done for eq. (8) in Fig. 3.

The expressions (18) and (19) are meromorphic functions, which are excluded from the original Nyquist test. However, according to a generalised treatment, the stability can still be judged by this response curve. Stability, which means the existence of a steady state of small forced oscillation, is assured if the origin of the complex plane does not lie in the region bounded on the right by the curve of the characteristic function when traced at increasing frequency, and if a family of

" parallel " curves drawn to the right of this characteristic curve does not wrap back and cross the latter. The last condition means that any waviness in the curve must attenuate and not be magnified when the " parallel " curves are traced.

According to eqs. (18) and (19), it is easy, by substituting $\delta + i\,\Omega$ for $i\,\Omega$, to show that the waviness which is mainly due to the term with the factor $(1 - \eta_t)$ actually attenuates when the family of curves is traced. We can therefore apply the criterion in its simple form. The system is stable if the origin always lies to the left of the curve $1/C$ when traced at increasing frequency from 0 to $+\infty$. In the case of Fig. 3, it must always lie under the curve.

9. Discussion of the Results

Curves *b* of Figs. 3 and 4 show the values of $1/C$ and C according to eq. (8) for the same data as curves *a*, but taking eq. (20) into account, with $\zeta = 0{\cdot}002$. Curve *b* of $1/C$ lies nearer to the origin compared with curve *a*. The phase lag of the blower flow rate weakens the damping effect.

In the complete eq. (18), the two last terms with the factor $1/\lambda$ can be neglected, if η_t is not too small. Curves *b* of Figs. 3 and 4 can be considered therefore as an approximation of eq. (18) for $\eta_t = 1$, $m = 0$. If η_t differs from unity, the curves will become wavy due to the term with $(1 - e^{-i\Omega})$. Points with an integer number for $\Omega/2\,\pi$ are not affected. Between these points the curve $1/C$ bends upwards $(\eta_t > 1)$ or downwards $(\eta_t < 1)$, Fig. 3. The deviations are usually slight if η_t is not too small, but if the damping is already small then even a slight deviation may produce a serious effect.

The consideration of $m > 0$ shifts the curves downwards, i.e., the damping is generally weakened. From eq. (18) this effect can be constructed graphically from the curves for $m = 0$.

At high natural frequencies, the effect of m can be detrimental. For the data of Figs. 3 and 4, the stability would at once be destroyed by even a small m ($\approx 0{\cdot}01$). Actually, violent pressure surges were observed in the Brown Boveri laboratory on a set with similar data. A quantitative comparison with the theory was difficult since the values of ξ and ζ, and especially the acoustic conductance μ of the geometrically rather complicated valve channels, could not be determined with sufficient accuracy. There is still a certain arbitrariness in their definition which probably can only be eliminated empirically. However, the calculated and observed natural frequencies agreed satisfactorily.

Due to non-linearity, the amplitudes of pulsation will be limited even under conditions of instability. The pulsation phenomenon recurs following a similar kind of limit cycle to that of Poincaré, which can be constructed graphically in certain simple cases.

Soviet Machine Tools

SPECIAL PURPOSE EQUIPMENT AND MACHINES

By J. Mannin.

Following a review of recent progress in measuring and inspecting equipment given last month, this article opens with the borderline field between measuring and machining. Of topical interest are Russian achievements in tracing devices for performing machining by copying from a master. Two Russian machines for gear manufacture are described in some detail, owing to the insight and originality displayed in their design. The series will be continued next month by a description of lapping machines for the tool industry and a summary of several recent Soviet surveys on general aspects of machine tool engineering.

Measuring and Machining

The instruments and automatic inspection machinery described last month were those dedicated to measurement as a separate operation in the production process. Before proceeding with a survey of some recent developments in metal cutting machinery, it is appropriate to examine the borderline field where measuring and machining are inseparable.

Every fully automatic machine tool embodies such a combination and our references to machinery for automatic production lines can be re-read in this light. However, most automatics are based on the setting of stops and on cam motions designed to ensure the repetition of pre-set machining operations. They do not use the actual dimensions of the individual machined component for the control of the machining operation on it. In the terminology of control engineering, most automatics use programme control rather than feed-back control. Only feed-back control embodies the application of dimension sensing elements or tracers which can properly be called measurement.

Some fairly common applications of feed-back control in metal cutting are the control of the feed in cylindrical grinding machines by the dimensions of the component and the follow-up system of copying machines, particularly copying lathes. The former method of cutting tool control is a practical application of the true closed cycle principle, in which the controlling signal is the actual deviation of the component from a set value to which the measuring device is adjusted.

The copying principle uses for its signal the motion of a tracer over a master component. This does not eliminate all the errors which may arise in the operation. The difference is seen in the effect of tool wear on the two systems of control. The true feed-back control automatically compensates for tool wear but the copying principle leaves this source of error unattended. Although it is perfectly conceivable to combine the copying principle with true feed-back control, to the writer's knowledge this combination has not been adopted either in Europe, America or Russia.

The feed-back control in abrasive machining of simple cylindrical shapes is used as a high-precision method rather than a high production method. It is also embodied in some special types of grinding machines, notably in gear grinding machines and in thread grinders, such as those for the manufacture of taps. In recent Russian writings the large variety of combinations which can be used in the automatic control of machining by the results of measurement has been classified, but most examples refer to ideas, practices and equipment known elsewhere.

Some recent proposals for the control of precision machining which vaguely belong to this discussion of simultaneous measurement and cutting include the so-called " thermo-dynamic feed." In a grinding machine small feed displacements of the grinding spindle are

induced by the thermal expansion of a heated member in the feed transmission. The control of these displacements is effected by the regulation of an electric heating system. It is claimed that grinding machines so equipped can be more conveniently arranged for a feed-back control by the diameter of the machined component and that in this manner an accuracy of 2 to 3 microns can be consistently achieved in continuous production.

Another example of a recently developed correction mechanism is embodied in a machine, exhibited in 1952, for the cutting of lead screws, and other precision threads of great length (up to 2·5 metres). A correction is applied by means of a long straight cam mounted on the back of the machine which superimposes a rotation of the nut box in the apron to compensate for errors of the lead screw of the machine. The correcting cam is prepared after measurement of the errors of the machine, when mounted and operating on the shop floor, and therefore compensates all systematic errors. As a result, the accumulated systematic error nowhere exceeds 10 microns per metre.

Copying devices for lathes and milling machines are at present coming into vogue in Europe and America and some notes on Russian thoughts and designs may be of interest. It is perhaps too early to recognise systematic preferences. Fully electrical and hydraulic systems are in use or are under development, but no evidence has appeared of either pneumatic power or mixed systems, such as the electro-hydraulic.

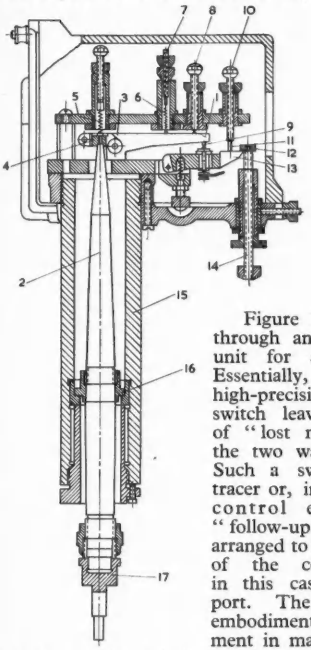


Fig. 1.

Figure 1 shows a section through an electrical tracer unit for a vertical lathe. Essentially, a tracer unit is a high-precision two-way limit switch leaving a minimum of "lost motion" between the two ways of switching. Such a switch becomes a tracer or, in the language of control engineering, a "follow-up switch" when arranged to follow the motion of the controlled object, in this case the tool support. The most common embodiment of this arrangement in machine tools is the mounting of the switch on the tool support itself. In the vertical lathe described, the tracer actuates electro-magnetic clutches, one for every direction of feed. These are controlled by the closing and opening of the upper and lower contacts (1 and 9) shown in Fig. 1. The rest of the mechanism is concerned with providing a freedom of motion to prevent jamming and to permit the necessary adjustments for contact positioning and the lost motion between them.

The central spindle (2), mounted inside the sleeve (15) in a spherical hinge (16), is free to move axially and to swivel in any direction about the centre of the spherical hinge. The lower end of spindle (2) carries an interchangeable tracer head (17), the diameter of which is selected in accordance with the dimensions of the cutting edge and the machining allowance. The opposite end of the tracer spindle is supported in a jewel bearing cup (4). The angle of its cone is so chosen that lever (3) is equally displaced by axial and radial displacements of the tracer head. Under the pressure of spring (5), the tracing spindle takes up its lowest position. Contacts (1) are then closed. Upon establishing contact between the tracer head and the master, contacts (1) are separated and contacts (9) are closed. In the event of excessive pressure between tracer head and master, contacts (11) are broken and switch off the motor completely.

The setting up of the copying device is performed by unscrewing screw (8) until a clearance is established between contact (1) and lever (3). Screw (8) is then screwed in to close contacts (1) and to form a clearance of 25-50 microns between the upper spherical end of the tracing spindle and the tapered bearing surface of (4). For the adjustment of the lower contact (9) in finish machining, screw (10) is turned until a clearance of 0·2 to 0·25 mm is formed between the contact (9) and the auxiliary lever (13). In this adjustment the auxiliary lever (13) must not touch the disc (12) and the screw (14). The spring (6) of screw (7) must ensure a reliable connection between the contacts (9).

A recent investigation was concerned with methods of comparison between several types of hydraulic circuits for hydraulic copying devices. The main theme of the study is the suitability of the so-called differential hydraulic jack, as used in most European hydraulic tracers and many other hydraulic servo-controls. This is shown diagrammatically in Fig. 2 and is characterised by the permanent pressurisation of one side of the cylinder facing a smaller piston area. Only the other end of the cylinder under the larger piston area is controlled by the tracer or follow-up valve. In this way the follow-up valve is simplified and the number of flexible conduits to the cylinder is reduced.

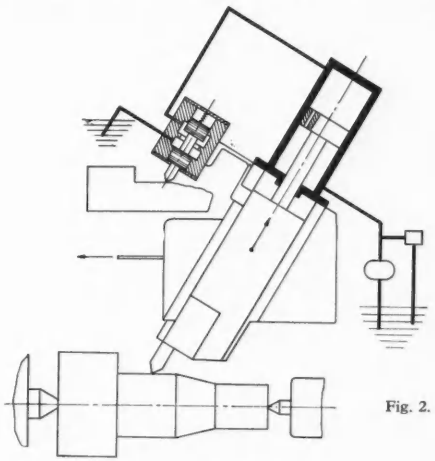


Fig. 2.

The conclusions derived from analytical study are summarised as follows :—

(1) Other things being equal, the "stiffness" of hydraulic copying with non-differential cylinders is greater and therefore ensures a greater measure of copying accuracy when cuts are deep and the load is variable.

(2) The lack of "stiffness" of hydraulic copying devices with differential cylinders can, in practice, lead to unacceptable errors. The stiffness can be improved if the follow-up valve is so shaped that the

cross-section open to the flow is reduced with an increase of the load.

(3) The greatest copying accuracy is achieved when the speed of response of the system is highest. This should be limited only by the occurrence of vibrations.

Soviet ideas on the significance of the copying principle claim that the principal advantage of copying systems is a reduction of setting time. A cam control automatic machine needs hours of setting (sometimes known as "kinematic setting" in Russia) whereas a machine working on a copying principle can be reset in a matter of minutes ("tool setting").

Another advantage of the copying principle, of special importance under Soviet conditions, is the ability to re-equip existing machinery. A copying lathe and a copying vertical milling machine recently exhibited are broadly hand-operated machines simply modified in the design stage. Each hand-operated clutch is replaced by an electro-magnetic clutch controlled by an electric tracing unit.

Some points of detail in recent designs of copying equipment are worth mentioning. A small vertical milling machine was brought out last year with a hydraulic copying unit which claims adequate precision in spite of feed rates of 300-400 mm/min. This is achieved by a special design of the hydraulic tracer in which a control valve of the piston type is artificially vibrated to reduce its effective friction to the minimum and to increase the sensitivity of the system. It is pointed out that hydraulic copying circuits permit much simpler feed mechanisms than electrical systems. Nevertheless, development is proceeding on new electrical systems and a heavy copying milling machine was brought out by the Sverdlov factory, equipped with an electric gauge type of tracing unit.

Bevel Spiral Gear Generator

The Gleason gear generator revolutionised the design of gearing, notably motor car differentials. Gleason has become the byword of a whole category of gears. It is therefore of particular interest to observe Russian attempts to re-create an original bevel gear generator using the Gleason principle. The first step was an enquiry to establish whether the spiral bevel gearing it produces was worth retaining. It was decided that the combination of technical advantages in gear design and productive advantages in gear manufacture is unique, and that the extent of use of spiral bevel gear in the automotive industry is already so great as to make any alteration into a vast investment, justified only by a substantial margin in favour of an alternative. This reference to accumulated investment is taken almost verbatim from a Soviet source, and is an interesting sidelight on Soviet industrial thinking.

To meet the special conditions of Soviet industry it is stated that the machine tools developed should embrace the largest range of gear dimensions in the smallest possible number of machine sizes. Furthermore, these machines should be capable of relatively economic use for producing small and large batches of components. Thus, particular attention was given to ease of resetting for a new batch. The result of Soviet development work is a prototype designed and made by ENIMS, the Central Research and Development Institution of the Soviet machine tool industry. This machine was described in February 1952 under the type designation 528. By this time it had undergone ten months testing and had been passed for batch production.

Although the principle of operation of the spiral bevel gear generator is not novel, it deserves restatement before some details of the Russian version are discussed. The gear generator is designed for cutting by the plunge method as well as for generation proper. When working as a generator, the machine reproduces the engagement of the gear to be cut with the imaginary generating bevel crown (the equivalent of the generating rack in spur gears). One of the teeth of the generating crown is replaced by the surface swept by the cutting edges of the rotating circular cutter. Thus, in the cutting of bevel gears, as in all generating processes, two motions are distinguished—the cutting motion and the rolling or generating motion. The former is simply the rotation of the cutter, the latter is embodied in the oscillating turning motion of the generating cradle, which incorporates the cutter spindle, and of the co-ordinated continuous rotation of the blank. The generating motion proceeds until the groove between two teeth is fully cut. After this the work is withdrawn from engagement with the cutter and the generating cradle is made to turn in the opposite sense until it reaches its initial position. During this motion the workpiece continues to rotate in the same sense as during the cutting process. These motions are so correlated that, during the return stroke of the cradle, the machined gear advances in its rotation by a number of teeth and is then brought back into the cutting position to start the machining of a fresh groove. This is usually not the neighbouring groove to that just completed. When all grooves are machined, the gear generator is automatically stopped.

In the rough machining of gears and in some special cases, the cutting is carried out by the plunge method, in which the feed motion is the advance of the workpiece into the cutter. In this method of cutting, the shape of the groove at each point of the machining cycle is a copy of the surface swept by the cutting edges of the tool. The rolling motion of the generating cradle is used only to the extent of switching over to the neighbouring groove after completion of the previous one. Wheels having straight flanked tooth profiles can be cut for use in so-called semi-generating gear trains. The bevel pinions which engage with such bevel gears can also be cut on the same gear generator with the help of a special mechanism for modifying the generating motion. This mechanism supplies the correcting generating motion. This superimposed generating motion modifies the profile of the pinion by taking off material from the pinion tooth flank, both below and above the pitch circle, to a depth progressively increasing with the distance from the pitch circle. The modifying mechanism can be used for carrying out any desired modification of the tooth profile, including such small modifications which ensure a particular location of the point of maximum pressure, as shown by the familiar pressure marks.

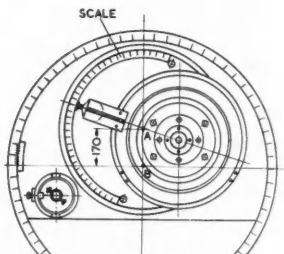


Fig. 3.

To achieve a correct setting of the cutter spindle it is mounted in an eccentric drum which can be turned in a bearing within the generating cradle (Fig. 3). The turning angle of the eccentric drum is adjusted on a scale after a simple calculation.

The transmission system of the machine can be sub-divided into separate parts, namely the cutter head drive, the generating motion mechanism, the disengaging mechanism, the accelerated return transmission, and the modifying mechanism.

The main interest in this machine centres on the generating motion and associated mechanisms. The core of this mechanism is the reversing transmission to the generating cradle. The essential part of this transmission mechanism is illustrated in Figure 4, and is of a type known as a mangle gear mechanism. The illustrated portion of the transmission receives its drive from the main power transmission through the wide faced gear (1) which engages the narrow gear (2) keyed to a shaft integral with the bevel pinion (3) in mesh with bevel gear (4). This bevel gear (4) is keyed to a shaft integral with the spur pinion (5) which engages with an endless rack of crescent shape made up of several parts and attached to the face of a disc at the end of a stub-shaft carried in ball bearings within the hub of a mounting plate.

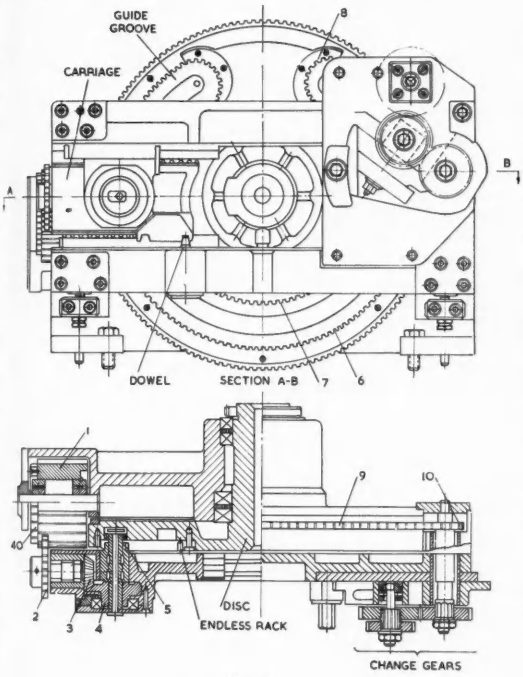


Fig. 4

The endless rack consists of four parts: (1) A crown (6) with internal gearing covering 7/8 of the periphery of the disc. (2) A crown (7) with external gearing also covering 7/8 of the periphery. (3) and (4) Two half-pinions (8) with internal gearing. The pinion (5) carries a roller which enters a groove formed in the face of the disc. The groove runs at a constant distance from the endless rack all along its circumference. This roller in the groove secures pinion (5) against disengagement from the endless rack.

The shaft of pinion (5), together with the pair of bevel gears (3) and (4), is mounted on a roller guided carriage which can move in the radial direction. The pinion (5) always rotates in the same sense and, engaging with the teeth of the endless rack, the latter is compelled to rotate together with the disc on which it is mounted in either one or the other sense. The sense of rotation of the disc changes when pinion (5) engages with the components (8) of the rack. As soon as this takes place, the pinion carriage, under the control of the roller and groove, is displaced in its guides from one extreme position to another. When the pinion (5) has traversed the whole length of the half-pinion (8), the carriage ceases to move and becomes locked in one position by means of a locking dowel.

The disc which carries the endless rack also has an external gear crown (9) which engages with the pinion (10). From here the transmission is continued through a spur gear grain to a set of change gears for the adjustment of the reversing motion. From the change gears a worm is driven through a bevel gear train. The worm engages with the worm wheel turning the generating cradle.

The rotation of the workpiece which is part of the generating motion is transmitted through a number of gear trains which contain another set of change gears and the final worm wheel drive of the work spindle.

The mechanism for feeding and withdrawing the work consists of a drum driven from the reversing mangle through a pair of spur gears and a worm drive. The reduction ratio is so chosen that the drum performs exactly one revolution during a complete cycle of the reversing mechanism, in other words, during the cutting of one tooth of the machined gear. This drum controls the hydraulic cylinder which performs the feed motion and also the automatic withdrawal of the work on completion of the cutting cycle and the final positioning of the work table into the loading position.

The transmission to the generating motion mechanism contains a friction clutch, which, during the cutting process, transmits the drive through a set of change gears for adjustment of the rate of feed and through a reduction gearing. As soon as the cutter ceases to cut, the friction clutch is automatically changed over to another branch of the transmission, short circuiting the reduction gear and the change gears. The non-cutting part of the machining cycle is therefore performed with an accelerated generating motion.

The modifying mechanism consists in essence of a means for imposing a controlled axial displacement on the worm in the final worm drive of the generating cradle. An axial worm displacement is equivalent to an additional rotation increment superimposed on the motion caused by the rotation of the worm. The correcting mechanism is driven by one of the bevel gears of the train leading to the worm drive and contains a set of change gears, by means of which the amount of modification can be adjusted.

It will be clear from the foregoing that the complete setting of the gear generator consists of the following setting operations: Selection of change gears in the feed transmission; positioning of work spindle and cutter spindle; selection of two sets of change gears in the generating motion mechanism, and selection of change gears in the modifying mechanism. The calculations needed for setting up are given in the form of tables and graphs.

Gear Grinder

Another creation by ENIMS for the gear industry, belonging to the most modern class of this type of machinery, is a semi-automatic gear grinding machine, also described in 1952. This is a machine working on the generating principle and was developed to overcome several shortcomings of existing types. It is said in particular that all existing gear grinding machines, with the exception of machines using an abrasive worm, contain a large reserve of unproductive time within the working cycle because the proportion of the time used directly for the grinding operation fluctuates between 10 and 50 per cent. The new machine is claimed to ensure continuous grinding and to contain an arrangement for an automatic control of the number of passes of the grinding wheel. Another feature which improves productivity is the simultaneous grinding of both tooth flanks forming the groove between two teeth. Moreover, the trueing of the wheel is automatic.

The design of the machine incorporates several

special features which are said to contribute to a high precision of the finished gear. The work rotates continuously and is not therefore subject to the errors which arise from the intermittent operation of an indexing mechanism. The dividing table worm wheel has a very large number of teeth and is made to a superprecision standard. Great attention is paid to the elimination of dimensional errors due to elastic deformations and temperature extensions. The gear grinder issued under a type designation 5P84 can take components up to 450 mm diameter and a modulus of 10 mm.

The general layout of the machine is as follows: The work carriage is guided on rollers along the longitudinal guiding surfaces of the machine bed. The carriage mounts the work table for loading the gear to be ground. The cross guides of the machine bed carry the grinding spindle carriage. A swivelling table is mounted on this carriage, having another set of guides on which the grinding spindle stock is made to reciprocate. During the grinding of a groove between two teeth the grinding spindle performs a fast reciprocating motion along the generator of the tooth, and the work slowly rolls along the teeth of the imaginary rack, the flanks of which are surfaces swept by the cutting edges of the grinding wheel.

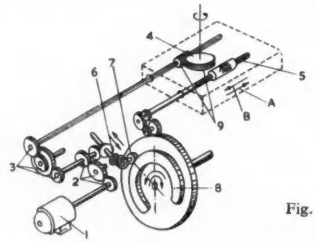


Fig. 5

The kinematics and some details of the gear grinder are represented diagramatically in Figs. 5, 6 and 7. The work (dividing) table (4) (Fig. 5) derives its rotation from an electric feed motor (1) through a reduction gear box (2), a set of change gears (3) and a worm drive (9) with a reduction ratio of 1·80. Throughout the grinding process of the component the table turns in a single sense. The carriage is propelled by a lead screw (5) which periodically reverses its sense of rotation and thus imposes a reciprocating motion on the carriage. The teeth are ground during the motion in the direction of arrow A. When the carriage starts moving in the direction B, the grinding wheel is withdrawn from engagement with the work by an upward displacement. Owing to the continuous generating rolling motion of the workpiece, another tooth is brought into position for engagement.

The reversing motion of the work carriage and its correlation with the continuous rolling motion of the work table are performed by a mechanism identical in principle with the reversing "mangle" mechanism embodied in the bevel gear generator (Fig. 4). A bevel gear train, driven by the input shaft of the dividing table change gears followed by a second bevel gear train (6), transmits the feed motor motion to a pinion (7) which is in principle identical with pinion (5) of Fig. 4. It is pointed out that the transmission gearing between the dividing table change gears and the generating motion change gears performs the same number of revolutions during the grinding of one tooth and the subsequent advance to another tooth, to improve the indexing accuracy. The change gears for the indexing motion are so chosen that each cycle of grinding, corresponding to one complete round of the endless rack (8), contains a turning of the component by a number of teeth which is prime to the total number of teeth of the component,

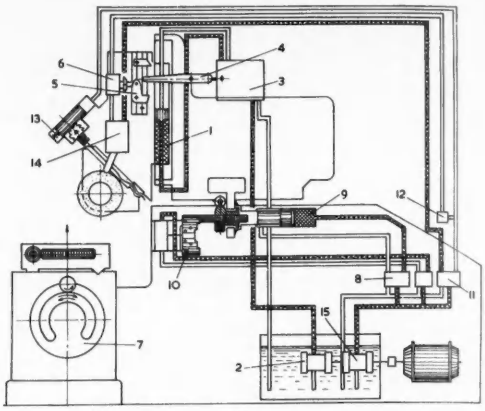


Fig. 6

but is not less than 7. Thus, for instance, if the gear to be ground has 40 teeth, each advance of the dividing motion can be 7, 9, 13 or 17 teeth, etc.

Fig. 6 shows the hydraulic system of the machine. The reciprocating motion of the grinding wheel is performed by the hydraulic cylinder (1), fed with oil by pump (2) through the hydraulic control panel (3) manipulated by the lever system (4) and adjustable end stops. After grinding of the tooth the stop (5) of the grinding wheel carriage is withdrawn by solenoid (6) and the grinding wheel moves upwards out of mesh with the machined component. The carriage performs its reverse stroke with accelerated speed obtained by an increase in the rpm of the feed motor. The duration of the return stroke is always 3 seconds. After the return of the work table into its initial position and the completion of indexing, another solenoid is energised and actuates the hydraulic control panel so as to initiate the downward motion of the grinding wheel carriage. Both solenoids are operated by limit switches mounted on the reversing mechanism indicated at (7) in Fig. 6. When the grinding of all the teeth is finished, a pre-set counter transmits a signal to the solenoid (8) which controls a piston valve and switches over the hydraulic circuit of pump (15) to actuate hydraulic cylinder (9), causing the grinding wheel spindle to pull away from the machined component. This motion causes a drum (10), which serves for the control and adjustment of feed, to turn automatically and reverse the signal to the electromagnetically operated piston valve (8). This valve returns to its initial position and the grinding wheel carriage moves forward.

For trueing of the grinding wheel before the beginning of a pass, the adjustable stops on the circumference on drum (10) actuate a limit switch which switches in the electromagnetically operated piston valve (11) to pressurize the hydraulic cylinder (13) of a ratchet mechanism which advances the grinding wheel against the trueing diamonds. When the grinding wheel has reached the required position, valve (12) is actuated and the trueing mechanism (14) comes into operation. When the trueing is completed the diamonds return to their initial position and the grinding of the machined component continues.

Fig. 7 shows a diagrammatic view of the feed control mechanism. The cavity (a) of the hydraulic servomotor receives pressure oil and tends to turn the drum clockwise. Pawl (1) butts against a stop (2) and prevents this turning. When solenoid (3) is energised pawl (1) swivels upwards and allows the drum to turn until another stop hits the rear extension of the pawl and returns the pawl to its initial position ready to

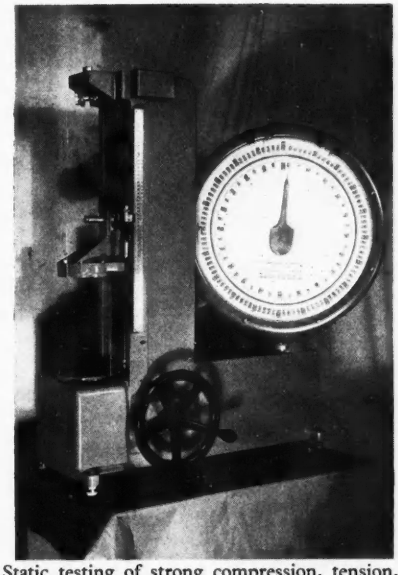
(*Concluded on page* 186)

New Materials, Processes and Equipment

SPRING TESTING MACHINES

A new series of special machines for the testing of springs of all kinds, known as the Probat series, is now being produced by Emmericher Maschinenfabrik von Gimborn & Co. K.-G., of Emmerich, Germany. The series consists of several types of machines and is designed to meet requirements for the static and dynamic testing of springs of all kinds and sizes. They operate on the same principle as that employed in quick-acting weighing machines, and the choice of loads which may be applied ranges from 1 gram to more than 60 tons. Most of the models are suitable for testing individual springs and for the serial testing of springs of the same dimensions. By incorporating a reversible measuring head in some of the models, two measuring ranges are available on the same machine.

Model BF 40 is intended for the static and dynamic testing of leaf springs and of bumper, compression, cup, and ring springs. It is available in ten ranges in capacities from 1 gram to over 60 tons and measurements are made with a maximum error of $\pm$ 0·2 per cent. The load is applied hydraulically in the machines of larger capacity and by means of handwheel and spindle in small capacity machines.



Static testing of strong compression, tension, cup, and ring springs, etc., and also of long springs, may be carried out on model SF H. Loading capacities from 1 gram to 60 tons and over are provided by a range of eight machines. Hydraulic loading is employed and the velocity of the stroke can be varied. This model can also be used for the shaping or setting of springs and for fatigue testing. The static testing of long tension and compression springs may be carried out on model SF 21 N (illustrated). Loads of from 1 to 500 kg may be applied by means of a handwheel and spindle.

Model SF 21 T, one of the most useful of the series, is a bench model used for the static testing of long tension and compression springs and also for spring elements of other kinds. Loads of from 1 to 1000 kg are catered for in five separate ranges. Two measuring ranges, having loading capacities of either 0 to 100 and 0 to 500 kg, or 0 to 200 and 0 to 1000 kg, are available with machines having a reversible measuring head. The desired degree of spring deformation is obtained by means of a self-braking spindle operated by a handwheel which can be placed on the right or left-hand side of the machine.

The load is indicated automatically by a non-oscillating pointer on a large circular scale, from which measurements are made with a maximum error of 0·2 per cent. A stroke measuring bar on the machine is located within the same angle of vision as the load indicator. On this bar, which is graduated separately for tension and compression, the deformation of the spring under test can be read by means of verniers accurate to within 0·10 mm. For serial tests, stops can be adjusted to accommodate the length of the springs to be tested.

A motorised version of model SF 21 T, which is also available, permits semi-automatic operation for serial testing. The operator feeds and removes the springs and notes the test results. In this version, the motor is coupled to the spindle which moves the pressure head. Two movable limit switches, located on a rail beside the vernier measuring bar, are adjusted when the spring length is changed. During serial testing, the pressure head moves up and down automatically. A time delay switch holds the pressure head in its terminal position for some seconds, during which a more exact reading of the load can be taken.

Models SF 25E, SF 51/SF 53, and SF 52 are hand lever operated and are intended for testing tension and compression springs, having the loading ranges 10 to 100 kg, 2 to 10 kg, and 500 and 1000 gr, respectively. Other machines have been specially designed for testing torsion springs and for measuring torque. These models are available in load ranges of from 2 cm kg to over 1000 cm kg.

AUTOMATIC CONTROL OF GLASS FEEDER TEMPERATURE

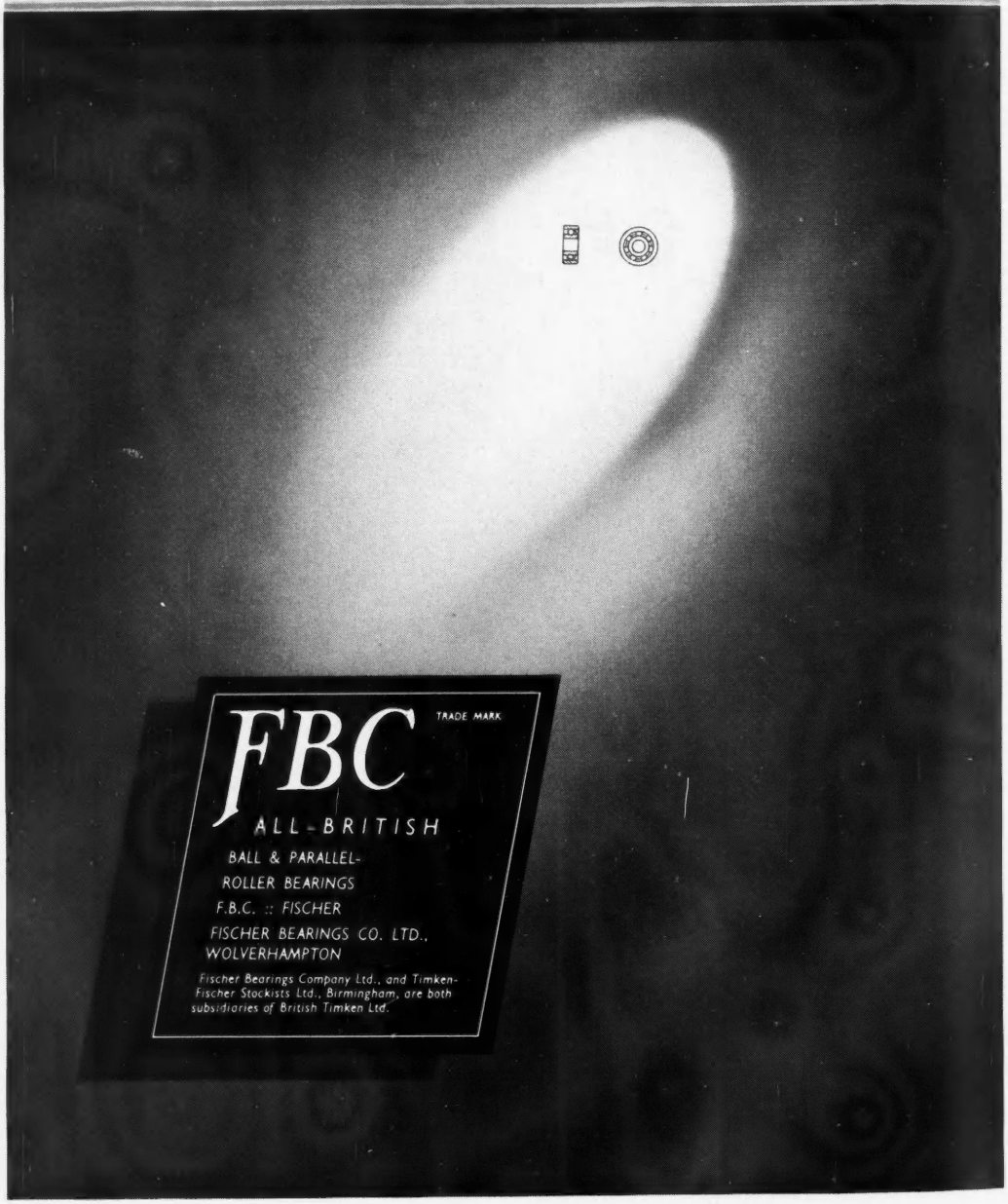
George Kent Ltd., of Luton, have developed a system of automatically controlling glass feeder temperature, using their " Mark 20 " air-operated control equipment, which ensures that a consistent temperature is maintained at the feeder spout, thereby ensuring a constant viscosity at the scissor mechanism, and a consistent weight of glass in each " gob." The application of automatic control of temperature speeds up production, reduces the number of rejects, and eliminates large variations in product weight caused by temperature changes.

The operation of the Kent system is as follows : Immersed in the molten glass in the feeder is a platinum/platinum-rhodium thermocouple encased in a platinum sheath to resist erosion. This thermocouple is connected to a " Multelec " recording potentiometer. Fitted inside the potentiometer case is the " Mark 20 " controller, which operates so as to vary the high-pressure air supply to the inspirator of the glass feeder burners, thus altering the heat input to the combustion chamber. Wastage of high-pressure air is virtually eliminated. The control temperature may be set at any desired value.

A manual control panel, fitted under the potentiometer, enables operators to control the plant by hand from the instrument location, during repair or on shutting down the plant, or when starting up a new

Miniature bearings

TO ALL SIZES AND SPECIFICATIONS



feeder. Signal alarms warn operators when the control valve is at the limit of its travel in either direction.

On feeders over six feet in length, it is usual practice to have two controllers, one for the channel section and the other for the spout.

LARGE WORKSHOP PROJECTOR

This instrument has been developed by Optical Measuring Tools Ltd., Maidenhead, Berks, a member of the Newall group, to enable the toolmaker to finish profile work visually and with a greater degree of accuracy. The design brings all controls within easy reach of the operator, who is able to stand conveniently near to the screen. Near the focal plane of the projection lens is mounted a vice which enables the workpiece to be positioned in the focal plane of the lens so that the finishing cuts may be made with the work imaged on the screen. This rigidly constructed vice is mounted on compound slides which permit a vertical adjustment of 4 in., a lateral adjustment of 3 in., and a focussing movement of 3 in. Built on to the side of the projector is a second vice which enables the operator to take heavy cuts on the work without returning to his bench.

An enlarged drawing of the desired profile may be attached to the screen by means of clips provided thereon. The screen is also fitted with adjustable locators for positioning a straight edge horizontally or angularly.

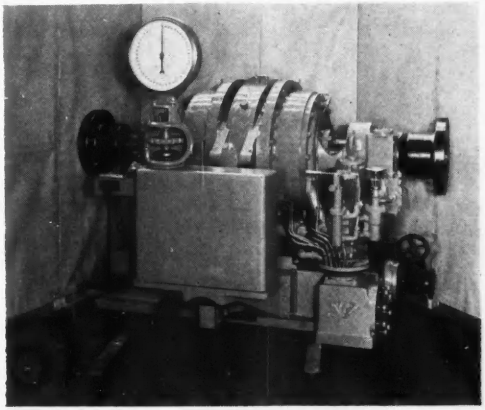
It is possible to set the magnification to any value between 19·3x and 20·2x making it possible, e.g., in the case of a die, to allow for a known metal contraction. The magnification change is effected by moving the carriage, containing the workholder, lamphouse and lens. A suitable rack and pinion control is provided for this purpose and magnification scales are built into the bed of the projector.

Lighting is provided by a 250 watt high pressure mercury vapour lamp with a suitable condensing lens system. The electrical control gear for the lighting is contained within the instrument.

A graticule is provided which is mounted to fit into the vice to enable the magnification to be checked at any time. Similarly, a smoked glass trace or photographic negative may be projected for comparison against a master drawing.

DIRECTLY REVERSIBLE HYDRAULIC DYNAMOMETER

Heenan and Froude, Limited, have just delivered to Messrs. Ruston and Hornsby, Limited, one of their directly-reversible Froude Hydraulic Dynamometers for testing diesel engines up to 1,500 bhp at speeds between 350 and 800 rpm. With this machine, one of Heenan's latest designs, the entire control of load and speed is carried out by one small handwheel seen in the accompanying illustration to the left of the half-coupling on the right side of the dynamometer. For engine governor tests, the operation of the horizontal lever (shown in the foreground) suddenly throws off the load.



The cabinet at the front of the machine contains the reversing levers of the torque measuring apparatus so that the main torque balancing weights are always lifted regardless of the direction of rotation of the dynamometer. Fine readings are taken on the vernier dial.

INJECTION MOULDING MACHINE

The development of a new plastics injection moulding machine designed to meet the requirements of the rapidly expanding plastics industry has been announced by the Lewis Welding & Engineering Corporation, of Bedford, Ohio, U.S.A. Features of the machine include multiple packing of the injection cylinder, quick mould release for nozzle clearance and the Hydra-Lock, a new method of clamping the moulds together. The machine will enable moulders of plastics to realize the full potentialities of the new plastic materials available. It is simple in design and operation, prime cost is low and its operators can be trained in a few hours.

An externally heated, straight-bore injection-cylinder is employed and the plastic material, which is fed into the cylinder by gravity, is packed into the heating section by multiple injection strokes. This pre-packing operation serves to compress the material, thereby reducing the bulk factor, and ensures maximum injection of the plasticised material. Injection of the material into the mould is compensated electrically. By proper adjustment of the control circuits, the heating chamber is starved by a small amount on each stroke until it strikes a limit switch which causes its return to a point of maximum retraction. From this point the process of progressive starving is repeated so that the machine completes its feed and injection in compensated balance. The normal injection pressure can be varied from practically zero to 20,000 psi and, by reducing the diameter of the injection plunger, it can be increased to 30,000 psi.

The clamping mechanism of the machine embodies a toggle linkage device on which the moving half of the

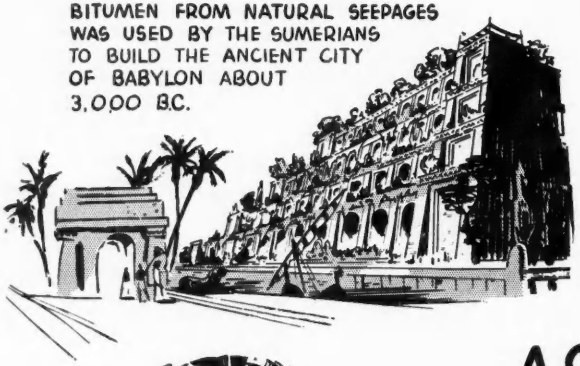
THE WORLD'S FIRST OIL MERCHANT

IN 1848 SAMUEL KIER, AN ENTERPRISING AMERICAN MERCHANT MARKETED 'SENECA OIL' CLAIMING THERE WAS HARDLY A DISEASE IT WOULD NOT CURE. 'SENECA OIL' WAS MERELY ORDINARY CRUDE OIL TAKEN FROM A SEEPAGE AT TARENTUM, NEAR PITTSBURGH.

Did you Know?

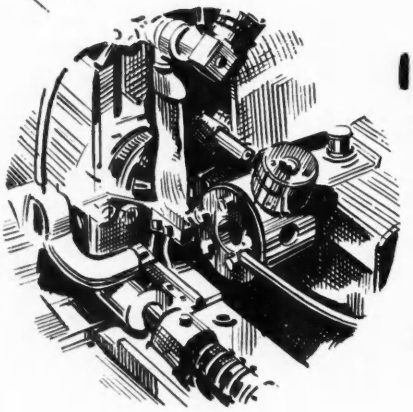
ANCIENT BABYLON

BITUMEN FROM NATURAL SEEPAGES WAS USED BY THE SUMERIANS TO BUILD THE ANCIENT CITY OF BABYLON ABOUT 3,000 B.C.



PIPE LINES THAT BRING PROSPERITY

PRESENT-DAY PIPELINES OF STEEL CONSTRUCTION CARRY 15,000,000 TONS OF OIL ANNUALLY— IN THE U.S.A. ALONE THERE ARE OVER 150,000 MILES OF PIPELINE, ENOUGH TO GIRDLE THE EARTH 6 TIMES.



A CUTTING OIL IN YOUR HEADSTOCK!

ONE OF ESSO'S STRAIGHT E·P CUTTING OILS IS ESSO CUTTING OIL Nº 2 IT HAS OUTSTANDING MACHINING PROPERTIES AND AT THE SAME TIME IS RECOMMENDED FOR USE IN MACHINE TOOL HEADSTOCKS AND GEARBOXES

It pays to say **ESSO**

Cutting Oils

ESSO PETROLEUM COMPANY, LIMITED, 36 QUEEN ANNE'S GATE, LONDON, S.W.1

mould is mounted. The toggle mechanism advances the platen to a position where the mould faces are only a fraction of an inch apart, and serves as a mechanical locking device to hold the platen in the closed position. A 16 in. dia. automatically actuated hydraulic cylinder, having a short stroke, is incorporated in the platen structure. This closes the moulds and supplies the final locking pressure. A clamping pressure of 200 tons is necessary to oppose the high injection pressures which the machine can develop. The new design of clamping system simplifies the mould-setting procedure by permitting quick line-up of the mould faces. The machine will tolerate considerable misalignment of the mould faces but still give uniform bearing across the mould. The clamping cylinder is provided with ball-and-socket action.

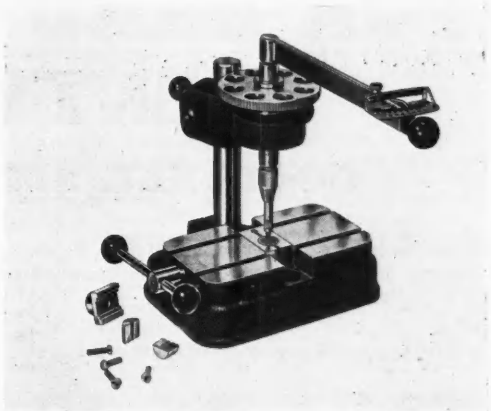
Closing of the safety gate starts the moulding cycle. The platens are then automatically advanced, the Hydra-Lock cylinder closes the mould and the material is injected. Pre-packing of the injection cylinder takes place during the curing cycle. At the conclusion of the cycle the mould opens and remains open to permit manual removal of the finished part. All of these operations are automatically controlled, but each part of the cycle can be adjusted to suit the mould to be used. Closing of the safety gate starts another cycle.

The capacity rating of the machine is determined largely by the size of the moulds and the material being moulded. The injection cylinder has a plasticising capacity of 60 lb of polystyrene per hour and shots weighing 6·8 oz have been moulded satisfactorily at the rate of 2½ per min. The machine weighs a total of 8,000 lb and will produce with rapidity difficult-to-mould products, free from flash and with a minimum of scrap.

TORQUE TESTING FIXTURE

The P. A. Sturtevant Co., Addison, Illinois, announces a new torque testing fixture with many practical uses. A fully adjustable spindle, set in instrument bearings, is held in rigid alignment and permits rapid engagement of the driver with the work. The spindle has a female drive square to accommodate a wide selection of torque wrenches. The driving end of the spindle is threaded so that users may design drivers for special applications. A standard male drive square attachment is included with each fixture and is fitted to the driving end of the spindle. This permits using regular sockets, socket screw drivers, etc., without alteration.

Illustrated is a typical application of testing the ultimate strength of a screw. This test and others will permit both the establishment of standard torque values and the inspection of screws by consumers to determine if they comply with their own requirements or those standards established for universal acceptance.



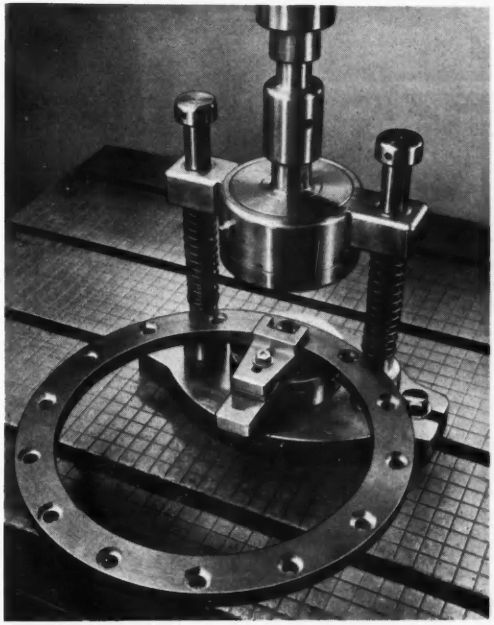
There are two models of the torque testing fixture now in production, with capacities of 0 to 200 inch-pounds and 0 to 150 foot-pounds.

POLYGON BOX FOR DRILLING AND BORING

A new design of polygon box has been introduced by Thos. Chatwin & Co., Ltd., toolmakers, of Birmingham, for operation with drilling machines. Previous models of the polygon box offered by this firm were lathe fitments which permitted the turning and finishing of polygonal shapes from round stock.

The new model is completely self-contained and is independent of the drilling machine. A spindle speed of approximately 200 rpm for revolving the box and an even feed of 0·001 in. per rev, preferably by automatic traverse, are necessary to operate the unit.

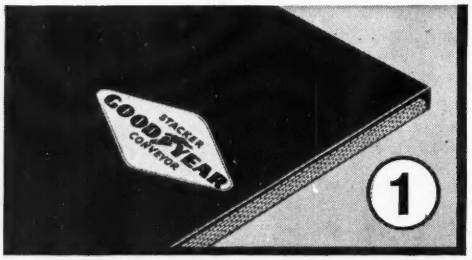
Work-pieces of any shape or diameter can be accommodated on the base of the unit and the shape and number of holes which can be machined are dependent on the fixture. The tool used for turning and boring is of substantial section and is easily ground.



FOR HARD WORK AND PLENTY OF IT–

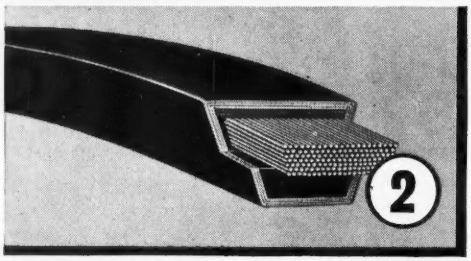
GOODYEAR BELTING AND HOSE

IN THE Goodyear range you will find conveyor belting for every type of service, transmission and V-Belts to suit every condition of loading, hose to meet every industrial need. Built with the accumulated knowledge of over 50 years' pioneer research and practical engineering, Goodyear Industrial Rubber Products give longer wear, more dependable service. And, above all, they keep operating costs to a minimum. That's why it pays to specify Goodyear.



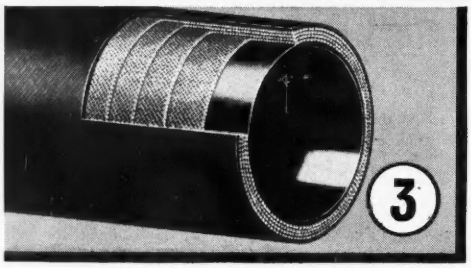
1 GOODYEAR CONVEYOR BELTS

The "Stacker" belt illustrated here is designed for installations which handle highly abrasive materials. Its tough resilient cover "gives" under impact and resists cutting. High grade bonding between the plies prevents separation under severe flexing. It is proofed against the ruining effects of mildew.



2 RAYON CORD V-BELTS

Goodyear Rayon V-Belts are ideal for all industrial drives, especially those longer, normal speed drives where shock loads occur. They stand up to sudden jolting loads that would break ordinary belts, for they contain strong, resilient, high-tensile rayon cords which "give" without snapping.



3 WRAPPED PLY HOSE

This Goodyear Hose is built from high-grade rubber tube wrapped in tough rubberized fabric for greater strength. A protective cover of bruise- and abrasion-resisting rubber assures lasting wear. And scientific arrangement of the fabric plies minimizes kinking. Intended for general service this wrapped ply hose gives long life under the most arduous conditions.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

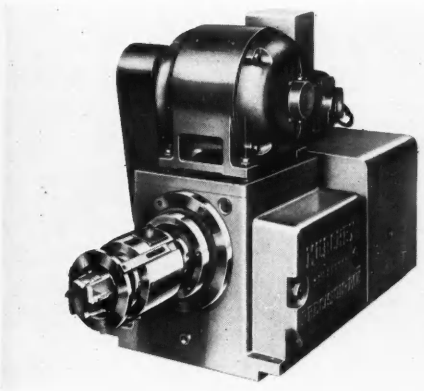
TRANSMISSION BELTING · V-BELTS · CONVEYOR BELTING · INDUSTRIAL HOSE

The Goodyear Tyre and Rubber Co. (Gt. Britain) Ltd., Wolverhampton

AUTOMATIC THREADING UNIT

A new Murchey " Precision-Pak " threading unit is announced by The Sheffield Corp. of Dayton, Ohio. The new device brings to the threading field a compact, fully automatic power unit with such features as direct precision lead, rapid return of the tool spindle, variable speeds, flexibility of application, and low cost of maintenance.

The Murchey " Precision-Pak " has a hardened and ground spindle driven by a 3 hp motor. Precision lead is maintained throughout the entire feed travel of 4 in. by a hardened and ground quick change lead screw and collapsible lead nut head which is mounted directly on the rear end of the spindle. At end of feed travel, lead nuts are automatically disengaged and rapid spindle return is obtained through a planetary gear clutch.



The unit is adaptable for mounting in almost any position, such as horizontal, vertical, or angular, in single, double end or multiples. Used in conjunction with Murchley collapsible taps and self-opening die heads, it is especially suitable for high production of such precision threading applications as shell tapping, rocket threading, aircraft, automotive, and other similar operations.

CATALYTIC EXHAUST-FUME PURIFIER

A catalytic fork-truck muffler that removes noxious carbon monoxide and hydrocarbon fumes issuing from gasoline engines has been developed by Oxy-Catalyst, Inc., Wayne, Pa.

Known as the OCM Catalytic Exhaust System, this new muffling device permits drivers to operate fork-lift trucks with complete safety in confined plant areas. It also prevents contamination of foodstuffs and other perishables that might be tainted by fork-truck exhausts.

The basic unit of the fork-truck muffler is the " Oxycat," which, in the OCM exhaust system, is a cartridge of spaced porcelain rods coated with a catalytic agent—catalytic alumina and platinum alloy. The engine exhaust flows across the surface of these rods where combustion of carbon monoxide and other harmful vapours takes place. On leaving the catalyst, the exhaust contains mostly carbon dioxide and water vapour, and only slight traces of the original contaminants.

OCM mufflers, which come in standard sizes for any make or size of fork lift-truck, contain two or more individual cartridges, depending on the size of the truck engine. In most cases the muffler attaches to the engine manifold. In each case the OCM unit replaces the regular muffler. Because of the streamlined shape of the catalyst rods the unit does not create back pressure.

The OCM muffler can be used on any engine—mobile or stationary—running on unleaded gasoline, and engines that have been running on leaded gasoline can be very easily converted for catalyst operation.

BRIDGE-NETWORK UNIT FOR FREQUENCY INDICATION

Crompton Parkinson Ltd., Aldwych, W.C.2, have developed a new sensitive bridge-network unit which enables any size of centre-zero moving coil instrument of a range 500-0-500 μA to be calibrated and used as a frequency indicator.

The network circuit, which is claimed to be practically immune from error due to abnormal waveform, consists of resistors, condensers and inductances arranged in a frequency sensitive bridge with half-wave rectifiers, giving a unidirectional output to operate the instrument.

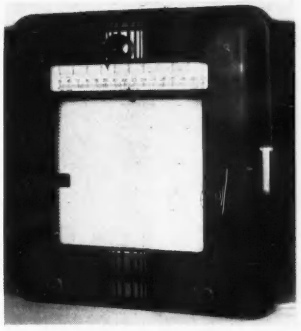
The network is balanced so that no current flows through the instrument at a pre-determined value of frequency. If the applied frequency differs from the pre-determined value, a unidirectional current proportional to the difference in a plus or minus direction, flows through the instrument and the pointer then takes up a position to indicate the actual frequency.

The bridge network is contained in a separate box approximately 7 × 5 × 4 in. deep. The unit is standardised for 45-65 ; 46-54 ; and 56-64 cycles at the present time and is for use on any voltage within the bands 100-120 V and 200-240 V.

The instruments are available in all the usual patterns, but in addition the following are available : circular scale, any size ; 3½ in. rectangular ; hermetically sealed, sector types ; and controller pattern including illuminated dial.

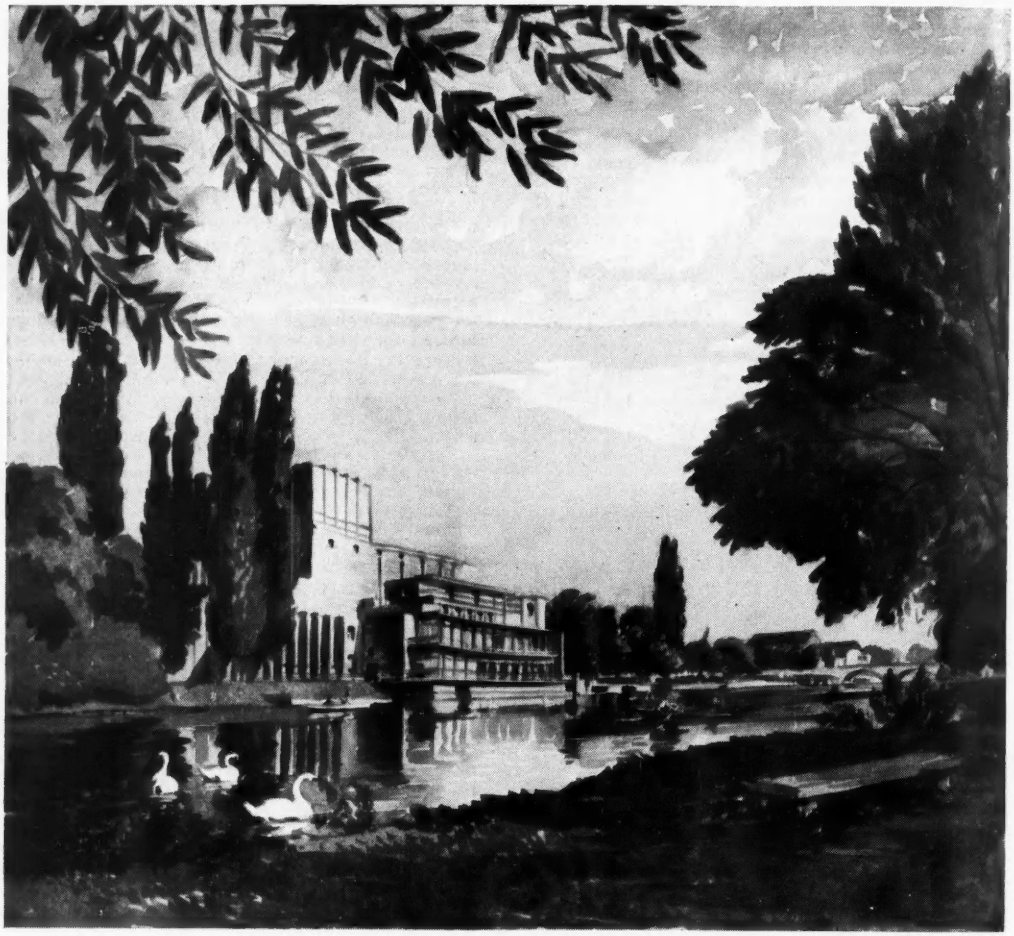
REVERSAL CONTROL FOR FURNACES

A new combined temperature recorder and temperature-difference controller for fast, accurate reversal of regenerative furnaces and glass tanks is now being offered by Leeds & Northrup Company of Philadelphia, Pa., U.S.A. The controller provides for the continuous recording of checker temperature, simultaneous measuring of temperature-difference between regenerators, and either automatic furnace reversal or warning for manual reversal when the pre-set difference is reached.



The instrument draws a two-point continuous line record of the temperature of checkers at opposite ends of the furnace. It does not record temperature difference as such, but plots a record of high and low temperatures, the width of the recorded band between them showing temperature difference. This distinctive record is easily read at a distance of several feet. The controller is available for use with either thermocouples or Rayotube detectors and it can be used in a complete Leeds & Northrup " packaged " reversal control system or incorporated with other reversal equipment.

(*Continued on page* 186)



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NEW BRITISH INSTRUMENTS

The following is a brief survey of some of the many interesting instruments and components displayed at the Physical Society Exhibition last April, or to be displayed at the British Instrument Industries Exhibition next month.

The FREQUENCY STANDARD type 761, produced by Airmec Ltd. of High Wycombe, Bucks., provides pulse and sinusoidal signals at standard frequencies of 100 cps, 1 kc, 10 kc, 100 kc, and 1 Mc. It incorporates a cathode-ray tube for visual frequency comparison and a separate heterodyne circuit with a loudspeaker for aural frequency comparison. The short-time frequency stability achieved is better than 1 part in 10^6.

An ELECTRONIC TACHOMETER and frequency meter, type 726, is also made by Airmec Ltd. and is shown in Fig. 1. This meter-type instrument indicates the frequency of any repetitive electrical waveform from 20 cps to 20 kc and is designed for input amplitudes of 0·1 to 20 V. For tachometer measurements, the rotary or periodic motion of a mechanism is converted by means of a photocell unit or a mechanical contact breaker into electrical pulses applied to the instrument. Speed measurements can thus be made up to 1,200,000 rpm.

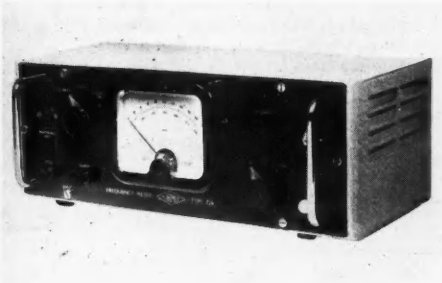

Fig. 1

A PRESSURE CONTROLLER to hold a vacuum system at any given pressure above 5 mm Hg is the Cartesian Manostat manufactured by W. Edwards & Co. (London), Ltd. The controller is made in both metal and glass models.

A STRAIN GAUGE MEASURING BRIDGE, type GM 5536/7, covering movements between 3 microns and 1 mm, has been developed by Philips Electrical, Ltd., of London, W.C.2. It can also be used with inductive displacement-type pick-ups and the frequencies covered extend from zero to 1000 cps.

Philips Electrical have also produced a SURFACE FINISH COMPARATOR with a piezo-electrical manual scanning element. Roughness standard specimens, type PR 9180, are included for calibration purposes, and the readings obtained through a high gain amplifier are indicated by a moving coil instrument.

Precision WAVEGUIDE COMPONENTS for the 8 to 10 mm waveband are now being made by Hilger and Watts, Ltd., of London, N.W.1.

A SPECTRUM ANALYSER, type TF 984/1, is being produced by Marconi Instruments Ltd., of St. Albans. The unit displays on a cathode ray tube screen the frequency spectra of centimetre wave outputs of S band transmitters in the frequency range. 2,900-3,150 Mc, using a mechanically tuned local klystron which is frequency modulated over a range up to approximately 10 Mc. Controls are provided for the determination of sweep velocity and spectrum width.

The SERVOGRAPH developed by Fielden (Electronics) Ltd., is an apparatus designed to record and, if required, to control electrical quantities. Instead of having a pointer, the moving coil meter is provided with a small vane forming one plate of a variable capacitor. The second plate is mechanically coupled to a pen-positioning servomechanism. Any change in spacing between these vanes causes the servomotor to operate so as to restore the initial spacing of the vane and hence the balance of the system. Cam-operated switches can be fitted to operate external circuits.

The "CINTEL" FLYING-SPOT MICROSCOPE, designed by Cinema-Television, Ltd., of London, S.E.26, comprises an optically flat scanning tube on which is reproduced an unmodulated 405 line raster. This raster scans a very small area of the stained or unstained specimen under examination. The transmitted light is modulated according to the shape and density of the specimen and falls upon a multiplier photocell, the output of which is amplified and used to modulate a synchronised raster on a 12-inch monitor tube. Any number of monitors can be operated from the apparatus and the final picture can be up to 20 × 16 ft in size. By using ultra-violet radiation, the resolution is as great as with conventional photographic methods. The apparatus permits accurate and automatic counting and sorting of particles.

A new range of "Kent Mark 4" AIR-OPERATED POWER CYLINDERS for the actuation of REGULATORS (valves, dampers etc.) in automatic control schemes has been produced by George Kent Ltd., of Luton. Their display also includes summating, averaging, biasing, integrating and differentiating RELAYS, as well as a complete boiler instrument and AUTOMATIC CONTROL PANEL. One of their Power-Cylinders is shown in Fig. 2.

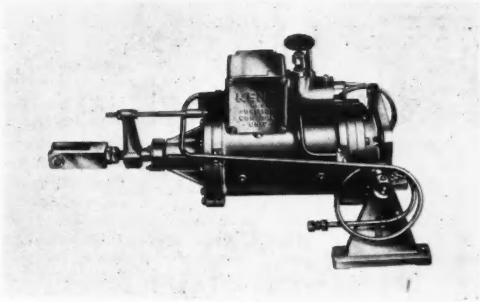

Fig. 2

A flexible, general purpose laboratory MAGNETIC AMPLIFIER, type MA 112, has been shown by Elliott Brothers (London) Ltd., of Lewisham, S.E.13. It incorporates two high-gain transductors, which may be employed either singly, in push-pull or in cascade. Each transductor has two input windings, feedback windings and bias windings with adjustable constants, and a series-connected a.c. winding.

Elliott Brothers have also produced THREE-DIMENSIONAL DISPLAY equipment. Two views of a volume considered from different angles are displayed alternately on a projection cathode-ray tube screen. The images are polarised in perpendicular planes so that, if the display is viewed through polaroid spectacles, a three-dimensional effect is produced.

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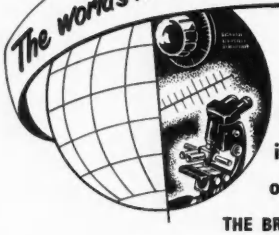

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A high-speed automatic ELECTRONIC DIGITAL COMPUTER has been developed and constructed by Elliott Brothers for the National Research Development Corporation. This computer, type 401, is a machine of moderate cost, is extremely reliable and easy to service, with standard plug-in "packages" for electronic circuits. It includes about 500 valves and operates at a digit rate of 333,000 per sec. The machine includes an input tape-reader and an output typewriter and is intended for solving mathematical and engineering problems which are too extensive for desk computing methods.

A VECTOR SLIDE RULE for multiplying and dividing complex quantities has been developed by the General Electric Co. Ltd., of London, W.C.2. It incorporates two cursors and two curved contour sections, which make possible the conversion of the parameters of a complex quantity in either orthogonal or polar co-ordinates. Quadratic and linear additions and subtractions are possible in direct combination with all ordinary slide rule operations.

A PEN-OSCILLOGRAPH UNIT, type EPR, with a flat frequency response within 10 per cent, from zero to 90 cps, is made by the Edison Swan Electric Co. Ltd., of London, W.C.2. The pen motor units are plug-in assemblies and the number employed may be varied between one and four. The apparatus includes a paper drive provided with a three-speed gear box, ink feeds and switching facilities, as shown in Fig. 3.

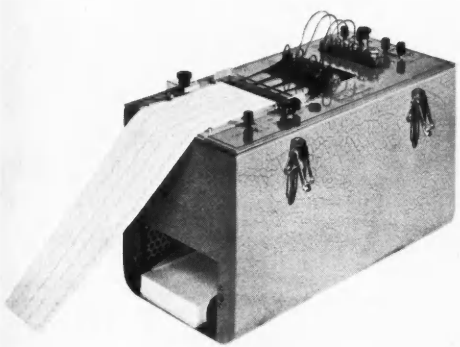

Fig. 3

The "ATOMAT" BETA RAY THICKNESS GAUGE, developed by the Baldwin Instrument Co., Ltd., of Dartford, is designed for the measurement and control of the thickness of materials manufactured in the form of strips, foils or sheets. The apparatus is produced with one, three, or six measuring heads, and is used in the paper making industry, in metal rolling mills, as well as for coatings, linoleum, rubber and plastics.

A new model DOUBLE BEAM RECORDING INFRA-RED SPECTROPHOTOMETER has been developed by Hilger & Watts Ltd., of London, N.W.1. The instrument is of the double beam in time type, in which the sample and standard beams are alternated with a frequency of 12·5 cps. In the standard beam there is a servomotor-operated shutter which modifies the radiation intensity to match that in the sample beam and transmits its movements to a pen recorder. The resultant curve is an exact representation of the absorption spectrum in the infra-red of the substance under examination.

An OUTPUT POWER METER, type TF 893, designed by Marconi Instruments Ltd., of St. Albans, for measurements on receivers, amplifiers, etc., is illustrated in Fig. 4. It covers a power range from 20 μ W to 10 W, with a flat frequency response from 50 cps to 25 kc. The input impedance is adjustable between 2·5 Ω and 20,000 Ω in forty-eight steps for balanced inputs, and a similar number for unbalanced inputs at one-quarter the impedance. The instrument is therefore particularly suitable for optimum load matching.

Fig. 4

A standard SERVO UNIT for automatic control applications is also produced by Edison Swan. The unit is designed for operation on 200-250 V, 40-100 cps. It includes a velocity feedback and accepts a d.c. signal. The motor provides torque up to 1200 gr cm and a speed up to 4000 rpm.

A RECIPROCATING DRILL operating at an ultra-sonic frequency, has been developed by Mullard Ltd., of London, W.C.2. In this instrument a high-Q magnetostriction transducer is used to generate vibrations at about 22 kc. These vibrations are transmitted to a drilling tip via a tapered metal stub, which acts as a step-up velocity transformer. This unit is particularly suitable for making holes, cuts and depressions in brittle materials or other materials difficult to machine by usual methods.

A versatile DOUBLE BEAM INFRA-RED SPECTROMETER at a moderate price has been made by Unicam Instruments (Cambridge) Ltd. for physical and industrial research. Double-beam operation is on the switching-in-time principle, employing a calibrated diaphragm inserted into the reference beam by a servomechanism and linked to the recorder, which uses a 10 in. chart width on a 12 in. diameter drum. In incorporates an evacuable optical system and automatic prism and wavelength cam changes. A Golay cell is used as radiation detector. Space is available for alternative radiation detectors, and cathode-ray tube presentation of spectra at cam repetition frequencies of up to 100 cps may be provided as an accessory. Automatic repeat scanning of portions of a given cam range is also possible.

A high-sensitivity type QUICK-RESPONSE RECORDER has been produced by Evershed and Vignoles Ltd., of London, W.4. This servo-operated instrument has a maximum sensitivity of ± 1 mV d.c. or a.c. and is designed to follow frequencies up to 10 cps. The instrument is designed for working from high-speed thermocouples or from strain gauges. The recording mechanism incorporates a two-phase induction motor, and variable damping is provided by a drag-cup generator coupled to the movement.

The HIGH RESPONSE RECORDER of Evershed and Vignoles is an instrument designed to fill the gap

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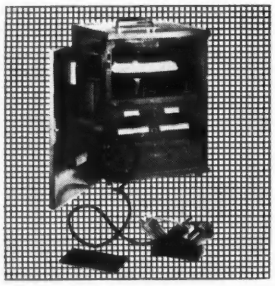

THE GLOSSMETER
One of the instruments on show, this compares surface gloss with that of a standard. It is compensated for variations in colour and brightness and the readings are made on a sensitive open-scale galvanometer.

It is based on a design by the Paint Research Station and is available for mains or battery operation. Size: 10" x 12½" x 14" high. Weight: 23 lb.

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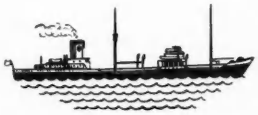

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between their Standard Recorder and the more elaborate amplifier-operated Quick Response Recorder mentioned above. The instrument has a 0·1 sec response for full-scale deflection and the torque is about eight times that of the standard recorder. The magnetic damping system is adjustable from about 54 per cent of critical to the overdamped condition. The same firm have also made a MINIATURE RECORDER, using an inkless high-speed tapping mechanism.

A PEN RECORDING POLAROGRAPH, developed by Evershed and Vignoles, incorporates a derivative circuit, facilities for completely undamped waves and special damping, a counter-current circuit and a dual speed potentiometer. The apparatus has 34 current ranges.

An experimental model of an AUTOMATIC TITRIMETER has been shown by Electronic Instruments Ltd., of Richmond, Surrey. This comprises a burette fitted with a solenoid-operated tap. A glass electrode system immersed in the liquid controls the tap through an electronic relay, which has an adjustable dial calibrated in pH. An accuracy of 0·1 pH can be reached under normal laboratory conditions.

An R.C. OSCILLATOR produced by Allied Electronics Ltd., of London, S.W.15, and shown in Fig. 5, has a frequency range of 20 cps to 200 kc and employs a balanced amplifier with cathode follower output. The output voltage is monitored by a $3\frac{1}{2}$ in. meter and the output attenuator is calibrated in volts and decibels.

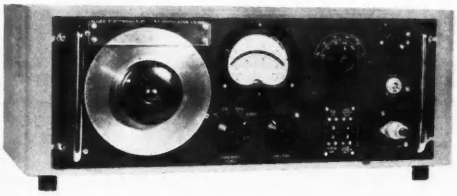

Fig. 5

An ultra-high speed IMAGE CONVERTER unit is produced by Mullard. The equipment includes an image converter tube and camera, and triggering and controlling circuits for the recording of high-speed phenomena. With a shutter duration of 1 μ sec stroboscopic observation is also possible up to 100 kc. The time resolution is of the order of 2×10^{-9} μ sec.

A PEAK-TO-PEAK MILLIVOLTMETER has been designed by Allied Electronics to meet requirements for a source of low-frequency a.c. for calibration of amplifiers and oscilloscopes. The instrument includes a screened and balanced transformer, a calibrated attenuator and a metering circuit. The output-terminal voltage is continuously variable from 100 μ V to 100 V and is indicated on a multiplier dial. The unit can be either mains-connected for use as a source of 50 cps, or used with an audio-frequency oscillator.

The portable DOUBLE BEAM OSCILLOSCOPE made by Allied Electronics is now produced with a smaller and lighter power pack. Two signals can be displayed simultaneously on the 6 in. screen without any detectable crosstalk. Both channels employ directly coupled amplifiers with a gain of 100 times and a band width of 0·5 Mc. Calibrating, recording and time-marking facilities are provided. The frequency of the electronic switch has been raised to 30 kc and alternate facilities are retained.

The "ALTRON" TIME INTERVAL METER is now made in five models by Allied Electronics, to cover different supply voltage control circuits and watch diameters. The latest models include a bayonet socket for retaining the electronically controlled stop-watch. The mechanical inertia of the driving system has been reduced.

The ISOMANTLE SURFACE HEATERS manufactured by Isopad Ltd., of London, N.W.3, have been applied to glass flasks and metal vessels of a wide variety of sizes. The accompanying illustration, Fig. 6, shows an application of electric surface heating to an enamelled cast-iron vessel of 20 gallons capacity, using Isomantle heating sections. The total loading is 3·6 kW and the heating surface is divided into three horizontal sections individually regulated by automatic controls, which can be set to any required temperature between 100° and 300° C (212-572° F).

Fig. 6

A CATHODE-RAY TUBE HEATING JACKET, developed by the Stabilag Co. Ltd., of London, E.C.2, consists of two half-portions which are assembled into a sheet metal casing, as can be seen from Fig. 7. The jacketing is made from fibreglass or quartz cloth in which a closely pitched resistance wire is secured. Various designs of case are available for specific requirements. A temperature of 400° C can be reached in 15 to 20 min. Other jackets are designed for the direct heating of liquids at a constant heat wavelength within the infra-red range. Each jacket is provided with multiple circuits covering equal areas, so that the entire surface of the vessel or pipeline can be evenly heated. Maximum temperatures are 500° to 700° C, and the consumption is 20 to 30 W. per square inch of surface

Fig. 7

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area. Various applications include embedding ovens for pathological laboratories, electric-jacketed food tilting and mixing pans, and rubber-lined electric-jacketed tanks.

The "ARKON" Model 1601 PRESSURE AND VACUUM RECORDER is a new instrument produced by Walker, Crosweller & Co. Ltd., of Cheltenham. With this instrument, illustrated in Fig. 8, the measurement and recording of pressure or draught or combinations of both are provided with high accuracy and sensitivity, as well as high magnification of very low readings (0·01 in. water gauge shows a movement of 0·2 in. on the chart). The parts are easily accessible and the

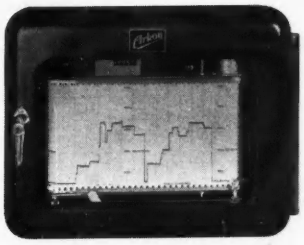


Fig. 8

unit is of compact and robust construction, which makes it particularly suitable for work under difficult conditions, as in gas works, steel works, foundries, etc. The roll of chart gives a continuous record for 6 weeks but any part of it may be cut off at will. The free end of the chart then travels over the chart plate and is picked up automatically on the collecting spool.

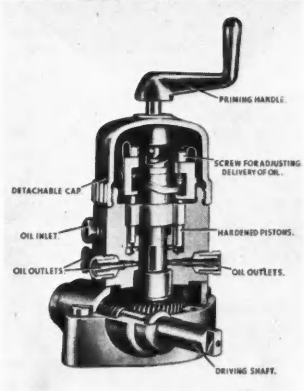
New Materials, Processes and Equipment

(*Concluded from page* 182)

CENTRALISED LUBRICATION UNIT

Details have been received from The Grease Appliance Co., of Cheshire, of a positive, centralised lubrication unit manufactured by Messrs. Hart & Son, of Rotterdam, Holland.

The Hart unit is designed to provide a system of central lubrication whereby the correct amount of lubricant is fed to each bearing of a machine. The amount supplied under pressure through each outlet to the bearings is variable by pre-adjustment of hardened steel pistons, one of which is allocated to each feed, as shown in the accompanying illustration.



Advantages claimed for the Hart centralised lubricator, which can be supplied for either automatic or manual operation, include the following :—It eliminates wastage of lubricant ; it permits continuous machine operations with no interference with production ; it removes accident risk occasioned by hand-lubrication ; and it ensures proper lubrication of all points positively and infallibly.

SOVIET MACHINE TOOLS

(*Concluded from page* 178)

eggage the next stop on the drum and prevent its further movement. The face of the drum consists of a number of protruding steps of different height, against which the end of the lead screw (4) of the grinding wheel carriage is pressed. The lead screw finds a step determined by the position of the stop (2) which therefore controls the depth of entry of the grinding wheel into the machined component for each pass. The drum carries another two rows of stops. One row serves for actuating the limit switch which initiates the trueing process, the other row to actuate the limit switch which terminates the machining of the component.

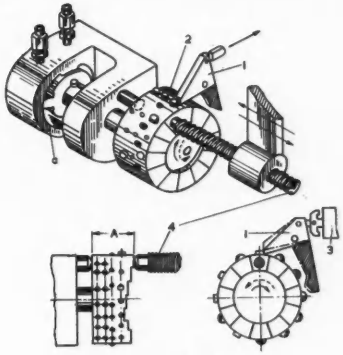


Fig. 7

The trueing mechanism is divided into two parts, one for the trueing of the straight flanks of the grinding wheel profile and one for trueing the periphery of the wheel. It is generally recognised that a precise formation of the radii at the bottom of the groove between two teeth is a most important property of gears subject to fluctuating loads. The trueing is performed by three diamonds, one for each flank and one for the corner radii and the top of the profile. The motion of the diamond carriers is hydraulically actuated and is precision guided by positive mechanisms. In trueing the flanks of the wheel profile, the straight flank can be replaced by a modified curve by means of a special cam which imposes a corrective swivelling motion on the diamond guides.

In other respects the gear grinder and its details follow standard practices which, as pointed out in one of the first contributions to this series, hardly differ from those employed in Western Europe and the U.S.A.

The claim made for these gear cutting and grinding machines in Russian publications is that in several important respects they show a marginal improvement over similar machines outside Russia. Convincing information in support of this claim is lacking, but on close examination production men will agree that these original designs apparently incorporate many features which show insight into the problems and understanding of the pitfalls of gear manufacture. It is, therefore, conceivable that this is one of the instances in which European engineers can learn something from Soviet achievements.

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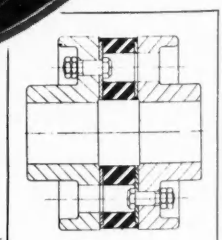
The D.S.P. Coupling comprises a centre coupling disc bolted between cast iron flanges; the method of assembly enabling valuable " man hours " to be saved by obviating elaborate " lining up " of driver and driven units.



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BRITISH INDUSTRIES FAIR, 1953

In last month's issue we published an advance review of industrial equipment shown at the British Industries Fair from April 27 to May 8. At the same time we expressed the hope that record attendance of British and overseas visitors would recompense the exhibitors for their efforts and expense incurred in connection with the B.I.F.

It is with much regret, therefore, that we learn that the number of visitors to the B.I.F. has considerably decreased as compared with last year's figures and even more as compared with the record figures of the first post-war years. The number of manufacturers exhibiting this year was also only 2,200 compared with 3,400 at the first post-war show.

One of the British Sunday papers published a most severe criticism of the Fair. "Thousands of overseas buyers are boycotting the British Industries Fair"—the paper wrote. "Hundreds of others have decided not to come again." "Dozens of exhibitors are tired of the B.I.F., too. They find it too expensive and are sceptical of its value."

In view of this and other criticism, we feel the Board of Trade should do some serious re-thinking in connection with the B.I.F. A larger and better exhibition, supported by more and better publicity, might offer one solution. Some co-operation with private exhibition organizers, who have, in many cases, the whole-hearted support of the Trade Associations, might be another possibility worth thinking about.

The coming years of increasingly competitive trade will also put exhibitions to a severe test. Only exhibitions which prove to be an economical proposition for both the organizers and the exhibitors deserve to, and will, survive.

In the following pages we continue describing some further exhibits.

On the composite stand of THE GAUGE AND TOOL MAKERS' ASSOCIATION, Standbrook House, Old Bond Street, London, W.1, forty-one participating members have displayed samples of their products.

J. E. BATY & CO. LTD., London, S.W.1, have shown dial indicator gauges of various sizes and styles from $1\frac{1}{8}$ in. diameter to $4\frac{7}{16}$ in. diameter with readings in ·001 in., ·0005 in., ·0001 in. or ·01 mm., dial test indicator sets, dial micrometers, small bore and cylinder gauges of various sizes, suitable for bores from $\frac{1}{2}$ in. to 36 in. diameter, bench gauges and comparators incorporating dial gauges.

BENRATH MACHINE TOOLS LTD., Manchester, have exhibited a Model "SE" static balancing machine for high precision balance of inserted tooth cutters, high speed cutters, turning fixtures, grinding wheels and similar parts.

B.S.A. TOOLS LTD., Birmingham, have displayed drills, reamers, taps and dies, ceramic tipped tools, die heads, high speed steel milling cutters, cast milling cutters, and broaches.

COVENTRY GAUGE & TOOL CO. LTD., Coventry, have shown floating carriage diameter measuring instruments, and Mirco-Maag internal micrometers.

FIRTH BROWN TOOLS LTD., Sheffield, have displayed a range of engineers' cutting tools of all types with particular emphasis upon their new mechanics' pocket drill sets.

JOHN HARRIS TOOLS LTD., Warwick, have exhibited a range of ground thread and cut thread taps and dies, screw plug and ring gauges, plain plug and ring gauges, plate gauges, screw plug, plain plug and ring gauges in Wimet, autogages and external caliper indicator gauges.

THE INDUSTRIAL FAN & HEATER CO. LTD., Evelyn Road, Sparkhill, Birmingham 11, have introduced the "Airflo" Resista Fan, designed to definitely resist the corrosive action of strong acids and alkalis and moist gases. It is constructed solely of rigid P.V.C., and all necessary metal parts are completely protected, the casing itself being fully lined with P.V.C. bonded to the outer shell of mild steel.

The Resista Fan is for use only where temperatures do not exceed 60° C or 140° F, and it may well revolutionise ventilating techniques in the plating and allied industries.

Also displayed was the Type "E" Dust Collecting Unit for dealing with dry, non-fibrous, non-explosive dusts with air temperature not exceeding 160° F. Its features are fully automatic shaking, mechanically controlled at specific intervals without interrupting production. Made on unit principle, it can be used in composite form according to requirements. Can be mounted on floor or steel supports at high level.

Other dust collecting and ventilating equipment including the K.F. Type Dust Collecting Unit which occupies minimum space and is suitable for dealing with all grinding dusts as well as wood sawdust, were also exhibited.

THE INDUSTRIAL PYROMETER CO. LTD., Gooch Street, Birmingham 5, have exhibited the IPCO Pyrostat, developed primarily to supply the need for a simple, reliable and inexpensive Temperature Controller for use with relatively small Heat Processing Plant, such as Heat Treatment Furnaces, Laboratory Furnaces, Diecasting machines, Plastics Injection Moulding and Extruding machines, etc.

Its design is completely unorthodox and simplification has been brought about by a considerable reduction in the number of component parts and the corresponding production cost involved.

There a two basic units in its construction :—

(a) A *control unit* which consists of a small electric motor with cam and chopper bar making periodic operations every half minute ; attached to this unit are two micro-electric switches having leaf operators spaced apart to provide a central null position.

(b) A *measuring unit* in which a pointer-type galvanometer with accurately calibrated temperature control setting scale attached, is mounted on a rotatable platform.

Thus, a change of temperature control setting is obtained by rotating the galvanometer relative to a fixed control mechanism, compared with the orthodox

"SPEEDICUT"

F. B. T.

FIRTH BROWN TOOLS LTD.

SPEEDICUT WORKS · CARLISLE STREET EAST · SHEFFIELD, 4

pattern in which the contro mechanism is itself adjusted.

In operation, temperature deviations from the control settings produce an electrical impulse of the appropriate kind " high " or " low," which actuate contactors for the switching of electrical heating or, for fuel-fired equipment, magnetic or motorised control valves for the regulation of gas and air supplies to the combustion system.

Control action may be of two kinds, two-position or proportional-position, and it will depend upon the time-response lag of the Heating Plant, coupled with the degree of temperature control limits required, which method should be adopted.

For the majority of applications the plant is responsive and a change of heating rate quickly produces a corresponding change of temperature. Two heating rates are sufficient for these installations, one rate in excess of, and the other less than that needed during operation.

Where the plant is less responsive, owing to high thermal inertia or design features, the proportional-position method provides automatic variation of the heat supply and, by elimination of the cyclic " hunting " of temperatures, closer control limits are secured with more stable plant operation. Fuel valves may be positioned to regulate the gas and air supplies. For electrical heating, and certain fuel-fired plant where magnetic valve operation is not upsetting to combustion, the change of heat supply may be varied by alternation of the duration of timed impulses.

An important feature is that the contactor or valve-gear supplied may be selected to provide the type of control action required—the same IPCO " Pyrostat " may be employed throughout. Thus, should an installation turn out in practice to be less " controllable " than originally contemplated an additional unit may be all that is required.

The IPCO " Pyrostat " therefore has considerable flexibility and, in addition to being used with small plant and as safety over-temperature limit controllers, it has a wide field of use for multi-zone plant and other applications requiring close temperature control.

MACROME LIMITED, Aldersley, Wolverhampton has shown a complete range of engineers' small tools treated by the Macrome process, including Drills, Reamers, Milling Cutters, Turning Tools, Taps, Dies, Bandsaws, Hacksaws, etc.

In addition a range of Hand Tools of all descriptions were displayed, such as Spanners, Screwdrivers, Hack-saw Frames, Saws, Slide Gauges, etc.

JAMES NEILL & COMPANY (SHEFFIELD) LTD., Napier Street, Sheffield 11, introduced several new " Eclipse " lines as well as " Eclipse " Hack Saw Blades in a new and attractive pack.

In the new lines, following on the recent introduction of the " Eclipse " Heavy Duty Rectangular Magnetic Chucks which were on view for the first time at the B.I.F., there is a new circular model, No. AX 475C, which is $4\frac{3}{4}''$ diameter. This small circular chuck weighing only $8\frac{1}{2}$ lbs. is an ideal addition to the " Eclipse " range for small precision lathe work. The Heavy Duty Chuck Model No. 1812 (independent and multiple types) is built upon the unit principle and can be built up to any desired length in 18 inch sections and serves particularly the heavy grinding, planing and milling spheres of production. Other Magnetic Chucks and Magnetic Aids to Production were displayed, including Magnetic Holders and Magnetic Floaters.

Three new types of Permanent Magnets include three sizes of Pot Magnets, $\frac{11}{16}''$, $\frac{13}{16}''$ and $1\frac{1}{16}''$ diameter, which can be used for many duties including door fasteners, holders, or for incorporating with tools, fixtures and machines. A series of Button Magnets in Alnico were shown in a range of sizes from $\frac{1}{2}''$ to $1''$ diameter for Magnetic Indicators, Magnetic Drives and for fasteners of various types, whilst the third addition is the " Eclipse " Minor Magnet, a small bridge magnet which will be found extremely useful in offices, stores, school and also in the home.

Industrial Magnets include many types in different materials for the Electrical, Radio and other industries and include new designs for Television Receivers.

The display included, along with a full range of angle plates both with webbed and open ends, the " Eclipse " Swivel Angle Plate which is supplied in two sizes, viz., $5''$ and $7''$. These are sturdily designed and accurately manufactured and allow maximum head room when in use. They can be set by means of a calibrated insert to permit any required angle. Along with other features, they have two tapped holes in the longitudinal edges of both base and swivel plates to provide for stop plates.

A range of box angle plates was shown in three sizes made from the same high grade seasoned castings and are of the same accurate finish. They are supplied in $3'' \times 2\frac{1}{2}'' \times 2''$, $4'' \times 3\frac{3}{8}'' \times 2\frac{3}{4}''$ and $5'' \times 4\frac{1}{4}'' \times 3\frac{3}{8}''$ sizes.

An " Eclipse " sheet saw of an entirely new design was introduced. This has a die cast handle to which is attached a flexible saw plate which accommodates, by means of simple clamps, a standard hack saw blade.

It will cut corrugated and other sheet material with ease and accuracy and without blade breakage, and because of its simple design fits snugly into the tool kit.

The display of " Eclipse " High Speed Steel Tool Bits included the " Eclipse " lathe tool set, comprising roughing tool, finishing tool, parting-off tool, boring tool, external threading tool and internal threading tool, all ground ready for use and supplied in a permanent wooden rack. The set is available in two sizes, $\frac{1}{4}''$ and $\frac{3}{8}''$.

For cutting wood, metal and many other materials, there is the new " Eclipse " back saw which is supplied with interchangeable blades $5''$ long. Other " Eclipse " products include the full range of Hack Saw Blades and Frames, Piercing Saw Blades and Frames, Fret Saw Blades and Frames and Coping Saw Blades and Frames, as well as a wide range of " Eclipse " Hand and Precision Tools.

THE NORTHERN MANUFACTURING CO. LTD., Gainsborough, have displayed Transmission Gears of all types, Geared Motors, Enclosed Worm, Spur, Double and Single Helical Units, Spiral Bevel and Straight Tooth Bevel Units.

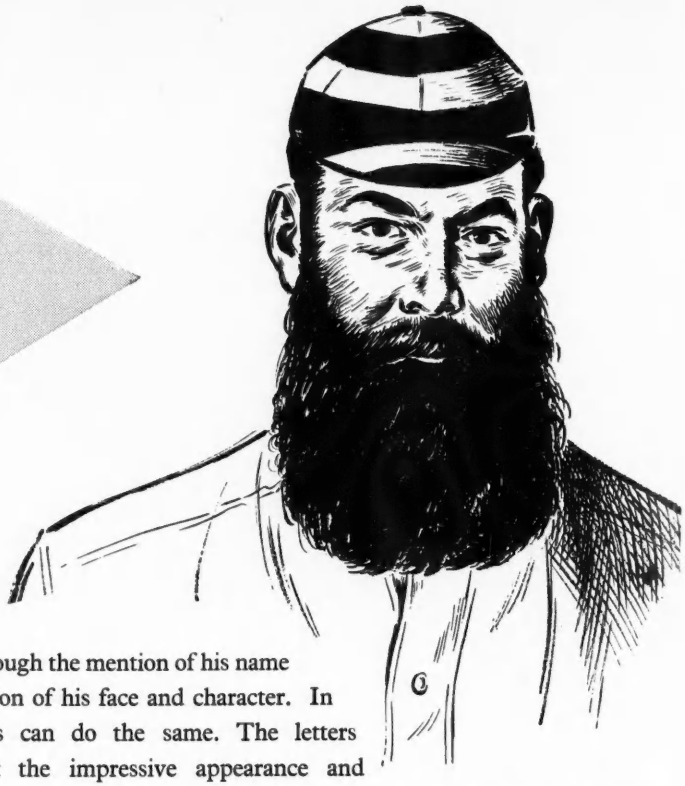
Pin type Couplings and Non-metallic Pinions have also been exhibited.

PERMALI LIMITED, 125 Bristol Road, Gloucester, has made a comprehensive display of laminated plastic materials and components designed to show the many applications of the Company's products to the heavy electrical industry, including generators, transformers and switchgear.

The exhibits included a display of arc extinguishing devices, a 132/33 kV transformer coil end insulating ring, $54''$ in diameter and $2''$ thick, a 300 kVA three phase distribution transformer to B.E.A. Specification T.1 fitted with Permali end ring insulation and tapping switch parts. An unusual exhibit was a portable Permali 500 m.m. sphere gap support arch of a type recently supplied to a transformer manufacturer for routine impulse testing.

Additional space was allocated to a display of bushing insulators for both switchgear and transformers, including 38·5 kV outdoor switchgear bushings. These were shown for the first time under the recently an-

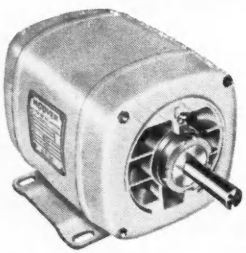
THE POWER OF A NAME



WHEN a man is famous enough the mention of his name calls up an instant impression of his face and character. In certain cases mere initials can do the same. The letters 'W.G.' certainly suggest the impressive appearance and famous achievements of the most renowned cricketer of all time. Linked with the name Hoover, the initials 'F.H.P.' have a similar power. To manufacturers everywhere they represent a fractional horse power motor that is unsurpassed for efficiency and quality, that will give the same smooth service for the whole of its long life. These manufacturers have *proved* that the name Hoover F.H.P. represents the world's finest 'fractional' — with the world's finest service plan to back it.

The Hoover F.H.P. Motor combines superb quality with competitive price. Please write for name and address of your nearest distributor.

HOOVER LIMITED



INDUSTRIAL PRODUCTS DEPARTMENT

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nounced trade name " DIALAM " which covers all the Company's bakelised paper tube and bushing products. A new low tension insulating material called " PERMA-BOARD " was also shown.

Another comprehensive exhibit was an almost full-sized model " H " pole of the type used in the construction of HV unearthed overhead lines, fitted with a Permali insulating cross bracing panel, Permali stay wire insulators, and a number of other standardised Permali parts and components for both constructional and maintenance purposes.

Permali silent gears, bearings and other general engineering parts have also been on show, and also a fabricated connecting rod for the operation of coal cleaning screens, as supplied to the National Coal Board.

The use of " Permali " for Arc Extinguishers has increased rapidly in recent years, and is now used as standard by several leading Switchgear manufacturers in the United Kingdom and Overseas. " Permali " has supplanted imported American Horn Fibre, and the material is so successful that tests are now being carried out by leading American Switchgear manufacturers. Quantities of component parts for Switchgear and Transformers to Canada and to the United States through Subsidiary Companies, Permali (Canada) Ltd., and Permali, Inc., are already being exported.

STANDARD TELEPHONES AND CABLES LIMITED, Connaught House, Aldwych, London, W.C.2, have demonstrated the impulse frequency system of telemetering which provides a simple system capable of transmitting readings of watts, vars, volts, amps, etc., over individual line circuits with facilities to permit a line circuit to be shared by a number of readings, particularly useful where it is expensive to provide multicore circuits. A special instrument has been designed to deal with system frequency, and an electronic device which will translate a direct voltage into a corresponding impulse frequency is also available as a transmitter for water level and similar position devices.

The system transmits impulses, the repetition frequency of which determines the reading. Line characteristics have no effect upon accuracy, and the system will operate over any line capable of transmitting impulses.

The display included a telemeter operating from an impulse source and indicating the accuracy obtained by using the system. Associated with the telemeter is an electronic distributor which enables a number of meter readings to be transmitted over one telecommunication channel. By means of the distributor the impulses are converted to teleprinter 5-unit binary codes operating at a speed of 50 bauds. A receiver accepts the impulses and a synchronised scanner re-allocates the received impulses to their telemeter circuits, which then respond in accordance with the received impulse rate.

A bank of capacitors was used as part of a demonstration to indicate, by means of meters, the improvements which can be obtained from the use of shunt capacitors on industrial distribution systems. In addition, an enlarged and remotely operated Power Factor Correction Calculator gives the capacitance required, and the saving in load after correction from the existing to the desired power factor. The demonstration was designed on a base load of 100 kW and indicated directly the reduction in kVA and the improvements of power factor obtained by inserting various values of capacity over a range of initial power factors. The resulting reduction in tariff charges could be easily deduced. The same display also demonstrated the way in which autocorrection operates to obtain the maximum improvements.

A novel feature of the capacitors shown is the built-in control unit comprising air-break contactor, isolator, fuses, control switches and indicating lights. This makes each capacitor self-contained with practically no increase in overall size, and results in greatly simplified installation, with a further advantage that only one size of the contactor is used for any size of capacitor bank. Extreme flexibility of adjustment of the size of switching steps is thereby provided.

Included in the range of Power Factor Correction Capacitors manufactured by " Standard " are high voltage types. Of new and advanced design, these capacitors have the advantage of small size, low cost and extreme reliability.

The exhibits included a selection of " telescope " samples and cross-section wafer samples of various voltages of power cables. Also displayed were Styrene Joints, and models illustrating Styrene compound, and the application of Styrene Barrier Joints to a cable route to avoid the build-up of pressure due to compound migration.

The Styrenated Joints shown are a 3-core 11kV joint and a 3-core 33kV " H " type joint. This latter type has now been installed in many parts of the world in considerable numbers, and has exemplary operating records. So far as is known this joint is smaller than any other 33 kV joint and is, in addition, a complete barrier joint.

The display of Rectifier Equipment consisted in the main of a demonstration of vehicle engine starting.

The new " Startall " Major, suitable for heavy diesel and petrol engines employing 12 and 24 volt electrical systems, is designed for the transport and public service vehicle operator. It is mobile, fully weatherproofed and attractive in appearance. Its use as an engine starter is demonstrated very effectively by cranking a large diesel engine even though the starter batteries are completely flat. The " Startall " Major can, in addition, be used for both slow and boost charging of vehicle batteries.

A representative range of radio valves was also displayed, including transmitting types, and those suitable for industrial applications.

The advantages of PVC Plastic Cables for industrial applications were emphasised by a display, which pointed to the use of these cables in an Oil Refinery.

For those interested in soldering, brazing, annealing and hardening, Standard Telephones and Cables Industrial Supplies Division, Footscray, Kent, have shown their Stanelco Electro-Gas Equipments on the Gas Council Stand.

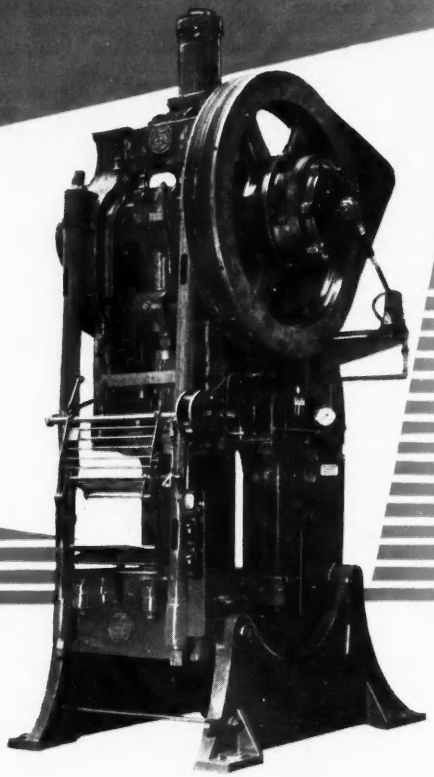
Equipment loaned by Monitor Engineering and Oil Appliances Ltd., of Stechford, was demonstrated. Using a total of 12 burners on the silver soldering of blow lamp bodies, 3 joints on each of 3 bodies were brazed simultaneously with silver solder melting at 750° C. The components were loaded on to a sliding jig and the heating time for these 9 brazed joints was only 35 seconds.

R. R. WHITEHEAD & BROS. LTD., Royal George Mills, Greenfield, Nr. Oldham, have demonstrated the wide uses for Felts by an extensive range of exhibits including Polishing Felts for Plate Glass, Polishing Felt wheels for engineering, Gaskets and Washers, Felts for the Aircraft and the Motor Industry, Oil Filters etc.

The " Regalpak " anti-vibration pads which simplify the anchorage of machinery to all types of floors and reduce vibration and noise, were also displayed.

" Regalpak " is resistant both to age and weather and to oil, solvents, light, heat and cold.

BLISS



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It's Bliss!

Swiss Industries Fair, 1953

Compared with a year ago the 37th Swiss Industries Fair, held from 11th to 21st April, has been enlarged by a provisional hall and additional open-air space.

The provisional tent was used for providing additional space required for exhibits of industrial accessories and domestic equipment. The new open-air space was occupied by the transport group. For the first time " LIGNUM," the Swiss Community Movement for the propagation of timber, has organized a " Timber Fair," a valuable addition to the extensive exhibits covering the building and furniture industry.

The Watchmaking Fair, a popular centre of attraction for years for experts from all parts of the world, provided an excellent display of the Swiss watchmaking industry which produces some three-quarters of the world's demand for pocket and wrist watches.

The technical industries occupied more than half of the entire exhibition space available. This indicates their importance in the Swiss economy and in the Industries Fair itself.

The extensive display of electrical goods was representative of the highly developed electrical industry. Machine tools and wood working machinery were shown in particularly large numbers. The textile machinery industry also offered an impressive display. Considerable interest was aroused far beyond Switzerland's national frontiers by the display of industrial accessories in which precision mechanics, the optical industry and the semi-finished products in the aluminium and non-ferrous metal industries were well represented.

The picture of the Swiss Industries Fair at Basel would not be complete without mentioning the representative exhibits of the Swiss chemical industry.

LETTER TO THE EDITOR

Sir,

We have noticed in your Blue Pages, a reference to Submerged Combustion equipment for use in pickling steel. The reference is such that it appears to be a new development.

We have received your magazine for many years and have found that it has been of considerable use to us in keeping up with new engineering problems. We object to this inference that Submerged Combustion equipment is new in the field of steel pickling. We have been doing this since 1932, and to further familiarize you with the equipment which we have been using in this work, we have enclosed two brochures.*

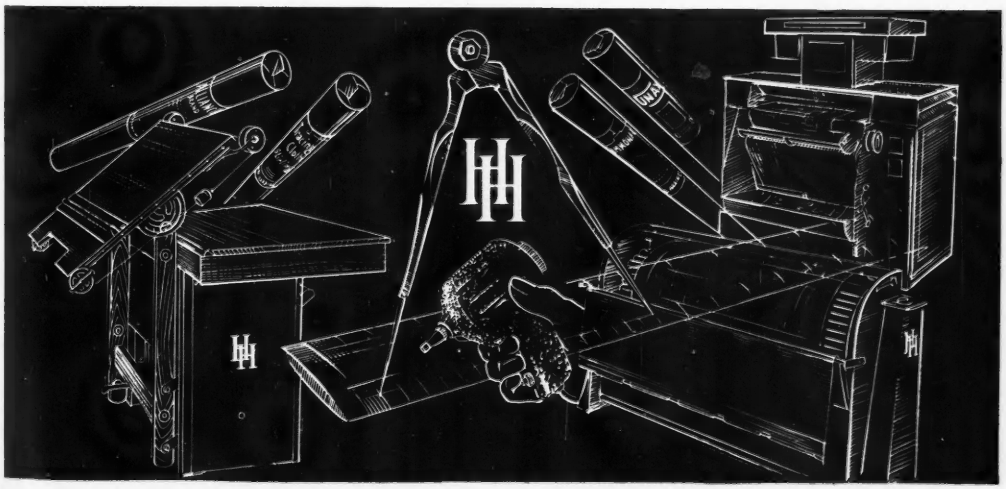
The blue one covering pickling, and the other is a general informative booklet on Submerged Combustion equipment. There are many applications of Submerged Combustion, as you probably know, in the chemical, petroleum, and steel industries. We are gradually becoming accepted in this country at least, in these industries.

If you are interested in receiving additional information, we shall be pleased to send it along to you. We felt, however, that you would be interested in our reaction to the small article on pickling which appeared in your journal.

Very truly yours,
WALTER GEORGE SEE,
President.

Submerged Combustion Co.
of America Incorporated
Hammond, Indiana.
March 12, 1953.

*We shall be pleased to send on loan the brochures mentioned in this letter to interested readers. Ed. E.D.



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PHILIPS INDUSTRIAL HIGH FREQUENCY HEATING EQUIPMENT

Philips Electrical Limited manufacture a wide range of High Frequency Generators and allied equipment for Induction and Dielectric heating applications, ranging, in the case of Induction heating, from the large 160 kW. generator down to one of only 2½ kW. Philips extensive experience in many branches of industry has been utilized in the design and construction of these generators. Three popular models are described below:

F.280 (160 kW) Generator :

Max. Power output at terminals	160 kW	Cont
Max. Power required from Mains	300	kVA
Power Factor	0.9	
Mains Supply Voltage — 380/440v. 3-ph	50	cycles
Nominal Frequency	200	kc/s

F.50 (25 kW) Generator :

Max. Power at Terminals	25	kW
Max. Power required from Mains	50	kVA
Power Factor	0.9	
Mains Supply Voltage — 380/440v. 3-ph	50	cycles
Nominal Operating Frequency	350	kc/s

F.5 (2½ kW) Generator :

Max. Power at Terminals	2½	kW
Max. Power required from Mains	5	kVA
Power Factor	.85	
Nominal Operating Frequency	520	kc/s

Other Philips Generators available are :—

F.150 (80 kW) Induction Heating Generator
F.100 (50 kW) Induction Heating Generator
F.26 (14 kW) Induction Heating Generator
F.18 (10 kW) Induction Heating Generator
F.13 (6 kW) Induction Heating Generator
DF.1500 (750 W) Dielectric Heating Generator
DF.6 (3 kW) Dielectric Heating Generator.
All the above generators conform to BSS. 1799.

PHILIPS also manufacture a range of allied equipment including Work Inductors and Concentrators, Flexible Water Cooled H.F. Leads, H.F. Change-over Switches, and Melting Units. For full information, please write to the address below.

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INDUSTRIAL GROUP, CENTURY HOUSE, SHAFTESBURY AVE., LONDON, W.C.2

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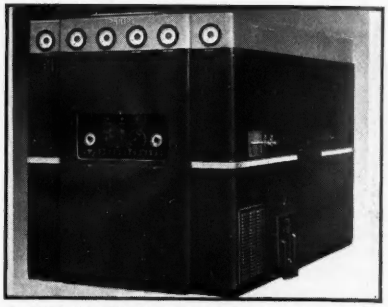
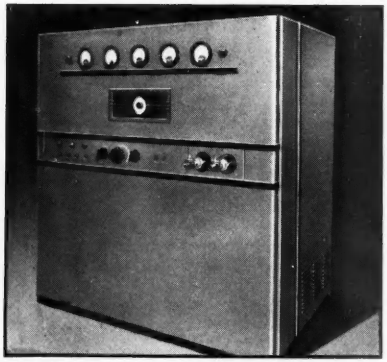
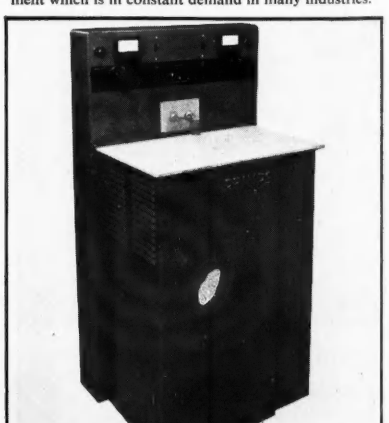


F.280 (160 kW) Generator: This is the largest valve-driven electronic heating generator in Europe, and its design incorporates the most modern features.



F.50 (25 kW) Generator: A medium-sized equipment which is in constant demand in many industries.



F.5 (2½ kW) Generator: Compact and extremely versatile, this low-powered equipment has proved increasingly popular.

(HF271)

NEWS OF THE MONTH

PERSONAL

Mr. Mervyn F. Boyd, technical manager, has been appointed a director of William Hamilton & Co. Ltd., shipbuilders, Port Glasgow.

Mr. C. H. Bradbury, M.I.C.E., M.I.Mech.E., M.I.Mar.E., chief engineer and technical director, at Petters, Ltd., Staines, has been awarded the Percy Still Medal by the Diesel Engine Users' Association for the best paper of the current session. The title of the paper was " Torsional vibration in diesel engines—some observations and practical aspects."

Mr. P. D. Canning has been elected chairman of the Radio and Electronic Components Manufacturers' Federation in succession to **Mr. H. V. Slade.**

Mr. J. Duthie has been appointed a director, and **Mr. R. C. Benson,** a special director of Darlington Forge Ltd., Darlington.

Mr. L. J. B. Forbes has been appointed general representative of Vickers Ltd., 165 Bloor Street East, Toronto 5, Canada.

Mr. R. D. Hamer, vice-president and director of Aluminium Laboratories Ltd., has been elected President of The Aluminium Development Association for the year 1953/54, in succession to **Mr. H. G. Herrington** who has been elected vice-president. **Mr. G. W. Lacey** has been re-elected chairman of the Executive Committee of the Association.

Mr. A. L. Hancock, B.Sc., has been appointed a director of Walker, Crosweller & Co. Ltd., Cheltenham, and of its subsidiary, the Arkon Manufacturing Co. Ltd.

Mr. H. O. Hinton, O.B.E., T.D., and **Mr. E. Cooper** have been appointed to the Board of A. C. Morrison (Engineers) Ltd., Loughborough.

Mr. T. L. Kendall has been appointed sales director and **Mr. P. H. Hylton, M.I.Mar.E., A.I.N.A.,** marine sales manager, of Ruston and Hornsby Ltd., Lincoln.

Mr. F. V. Pearson, a director of Vandome and Hart Ltd., North London Ironworks, Wenlock Road, N.1, has been appointed general manager of the company.

Sir Harry Pilkington has been elected President of the Federation of British Industries, 21 Tothill Street, London, S.W.1, in succession to **Sir Archibald Forbes.**

Sir Harry Railing, M.I.E.E., has been re-elected President of the British Electrical and Allied Manufacturers' Association, 36-38 Kingsway, London, W.C.2. **Mr. D. D. Walker, M.A., M.I.E.E.,** has been elected chairman and **Mr. E. H. Ball** vice-chairman.

Dr. Dennis Rebbeck, C.B.E., M.A., M.Sc., J.P., has been appointed deputy managing director of Harland & Wolff Ltd., Belfast. **Mr. H. C. MacEwan,** manager of the electrical department, and **Mr. W. H. Park, J.P.,** shipyard manager and head of the steel constructional department, have been elected to the Board.

Mr. G. C. D. Russell, A.F.R.Ae.S., has been appointed assistant managing director, and **Mr. J. H. S. Green, A.C.A.,** secretary, of Handley Page Ltd. and Handley Page (Reading) Ltd.

Mr. G. R. Volkert, C.B.E., F.R.Ae.S., has been appointed technical director of Handley Page (Reading) Ltd. **Mr. R. S. Stafford, F.R.Ae.S.,** has been appointed director of the technical department, **Dr. G. V. Lachmann, F.R.Ae.S.,** director of scientific research, **Mr. C. F. Joy, A.F.R.Ae.S.,** chief designer, and **Mr. G. H. Lee, A.R.C.Sc., B.Sc., D.I.C., F.R.Ae.S.,** deputy chief designer, of Handley Page Ltd.

Dr. S. W. Saunders has been appointed joint managing director of I.C.I. (Billingham Division) in succession to **Dr. R. Holroyd,** who has been appointed to the main Board.

Mr. S. Scott Hall, C.B., has been appointed head of the technical services, British Joint Services Mission, Washington, D.C., in succession to **Sir Alwyn Crow, C.B.E.**

Mr. G. N. Vansittart has relinquished his office of chairman of Vauxhall Motors Ltd., Luton, Bedfordshire, and has been elected chairman of General Motors Ltd., 23 Buckingham Gate, London, S.W.1. **Sir Charles Bartlett** has relinquished his duties as managing director and has been elected chairman of Vauxhall Motors Ltd. **Mr. Walter E. Hill** has been appointed managing director. **Mr. William Swallow** has been appointed managing director, and **Mr. Charles Faulconbridge,** general manager, of the AC-Delco Division of General Motors Ltd.

Mr. J. V. A. Watson, O.B.E., director and general manager of the Castrol oils department, has been elected to the Boards of the associate companies of C. C. Wakefield & Co. Ltd., 46 Grosvenor Street, London, W.1, namely, W. B. Dick & Co. Ltd. and J. B. Pillin Ltd.

Mr. J. Harold Wood has been appointed technical director of B. Thornton Ltd., Huddersfield.

GAS TURBINES OF THE FUTURE

Mr. W. E. P. Johnson, managing director of Power Jets (Research and Development) Ltd., at the Society of Engineers in London, on 4th May, dipped into the future of the gas turbine as a motive power for industry and all forms of transport.

" At present it is possible to identify about 130 different types of design of industrial gas turbines—existing or under construction—with a total capacity of 500,000 kW," he said, " and hardly a week passes without some new use cropping up. Industrial gas turbine projects are alive in the U.K., U.S.A., Canada, Sweden, Denmark, Holland, France, Switzerland, Italy and Japan."

" For example, I had an enquiry (which can be met) from South America for a gas turbine to run on the waste of crushed sugar cane, to enable a sugar factory to produce cold air for internal purposes; another for a plant to run on bought-out steam and produce compressed air, hot air and chilled air, all as a central service; and for a small engine to run on aluminium."

Of the future Mr. Johnson said :—

Steel Works :—The possibilities inherent in integrated steel works are well recognised. Broadly, this may consist in making blast furnaces self-driving, by using the sensible and chemical heat of their effluent directly useful for compression. It can be shown that great economy should result. Similar treatment may be accorded to open hearth furnaces.

Coal Mines :—Thanks to the imaginative enterprise of Sir Harold Roxbee Cox and his colleagues in the Ministry of Fuel and Power, there is to be tried the generation of power from the methane in coal mine ventilation air—which, I understand, is in the order of 1%—by treating the whole upcast as a combustible mixture.

Power Generation :—I foresee gas turbines for both base and peak load running on solid, or liquid fuels, on waste or primary gases, and on atomic and waste heat. These should be lighter, cheaper and easier machines than their competitors; in some cases, they will be combined with steam and diesel engines.

Shipping :—They will be in mercantile ships, taking up far less space and involving far less maintenance. In this (if someone can invent good reversing) I believe in mechanical rather than electric transmission.

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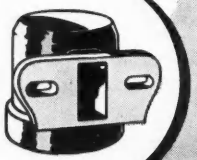

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Railways :—In locomotives they will exhibit their advantages of torque characteristic, ease of control, great economy of weight and volume and again I believe in mechanical transmission.

Road Transport :—Gas Turbines are on their way into road transport. They can and will beat the diesel engine in many important respects. I deny the dogma that they will be uneconomic in fuel. This dogma pre-supposes a limitation (that of bad part-load performance) which is not inherent. I expect soon to see a gas turbine yielding good efficiency at 15% to 20% on its full power and only slightly less efficiency at 100%. It will be—as I expect most fairly small units will be—a centrifugal-centripetal machine.

" The light and compact nature of gas turbines will bring them in for all manner of portable ' power pack ' uses ; for forward field installation in civil engineering undertakings, in the oil fields and on estates, and," he continued, " the possible military importance of portable power, quick starting and easy running is not overlooked. Other engines of war, such as armoured fighting vehicles, are known to be under consideration.

In a decade or two suitable components to build into a huge variety of systems will be available ' off the shelf.' The concept of enormous single-unit plants may vanish, to be replaced by many relatively small machines, any one of which will be regarded as replaceable.

The overall efficiency of such installations will be high over a very wide range of demand and the general trend will be towards lower capital cost, less elaborate ancilliary capital equipment, and a higher rate of replacement."

Concluding, Mr. Johnson said that wherever the earliest aspirations had had an opportunity to prove themselves, they had done so and it was guaranteed—by the weight of effort now directed to solve gas turbine problems—that no problem foreseeable would long remain unsolved.

ENGINEERING, MARINE & WELDING EXHIBITION AND THE CHEMICAL PLANT EXHIBITION

The 19th Engineering, Marine & Welding Exhibition and The Chemical Plant Exhibition will be held at Olympia (London), from 3rd to 17th September.

This is one of the major exhibitions of the year ; it is stated that nowhere else can buyers find assembled under one roof a more complete range of engineering equipment of importance to every field of industry. Exhibits will attract serious engineers and buyers alike.

D. D. Walker, M.A., M.I.E.E. will be the Honorary President, and the Exhibition has the active support and patronage of six leading associations.

The organizers are F. W. Bridges & Sons Ltd., and the director in charge of the Engineering, Marine & Welding Exhibition and The Chemical Plant Exhibition is Mr. R. W. Boardman. Advertising agents are Spottiswoode Dixon & Hunting Ltd.

LARGEST CAPACITY PORTABLE SUSPENDED WEIGHING MACHINE

Geo. Salter & Co. Ltd., West Bromwich, have received from The English Steel Corporation Ltd., Sheffield, an order for the design and manufacture of the largest capacity, portable suspended weighing machine in the world.

The machine will have a weighing capacity of 200 tons and will weigh castings of 168 tons each, produced for export. The machine will be the Crane Weigher Type which allows the goods to be weighed as they are loaded.

BRITISH THOMSON HOUSTON FACTORY IN NORTHERN IRELAND

The British Thomson Houston Co. Ltd., have decided to establish a Branch factory at Larne, Northern Ireland, and hopes to start production on a pilot plant in existing premises in about six months.

In the meantime the Ministry of Commerce will proceed as a matter of urgency with the acquisition of a site for the erection of a new factory in which, when it is completed, the Company propose to establish a manufacturing unit employing 200 to 300 workers of whom a high proportion will be men.

The Company has assured the Ministry that if they are satisfied with the progress of their first manufacturing unit they hope to develop productions in Northern Ireland sufficiently to build up their labour force to the region of 1,000 workers within the next few years.

THE BRITISH ELECTRICAL POWER CONVENTION

The Fifth British Electrical Power Convention will be held this year at Torquay, from June 8th to June 12th, under the Presidency of Sir John Hacking, M.I.E.E., Deputy Chairman (Operation), British Electricity Authority.

The theme of this year's Convention is " Electricity and the National Economy." The three principal Speakers will be Colonel B. H. Leeson, O.B.E., T.D., M.I.E.E., whose subject will be " Electricity and National Prosperity " ; Mr. E. R. Wilkinson, M.I.E.E., M.I.Mech.E. (" Electricity and Industrial Production ") ; and Mr. S. F. Steward, C.B.E., M.I.Prod.E. (" Electricity and Food Production ").

A feature of the Convention will be the popular Electrical Exhibition which this year will be the largest ever presented outside London, with the exception of the electrical section of the British Industries Fair at Castle Bromwich, Birmingham. Over 100 Exhibitors are to be represented and, while many Stands will be of interest to technicians, a large number will feature appliances and other equipment of particular interest to domestic consumers of electricity.

NEW MULLARD FACTORY FOR CATHODE RAY TUBES

As a result of the ever increasing application in industry of electronic devices and electronically controlled instruments, coupled with the very considerable increase in television, the Mullard Company has decided to establish a new factory for the manufacture of cathode ray tubes.

The present manufacture of these tubes is mainly concentrated in the Company's factory at Mitcham, London, and following discussions with the Board of Trade it has been decided to transfer the manufacture to a new factory to be built under the facilities provided by the Distribution of Industry Act in the North-West Lancashire Development Area.

The factory will be one of the largest and most modern television tubes factories and will provide employment for many hundreds of work-people. It will provide a valuable addition to the diversification of industry in the textile towns of North-East Lancashire.

The transfer of the work from Mitcham will make much needed space available for the manufacture of other electronic devices and this will absorb the workpeople at present employed on television tubes there.

The new factory will be within easy reach of the Company's existing factory at Blackburn which will be responsible for providing certain materials and component parts and services to the new factory. It is confidently expected that the provision of these services together with increasing demand for existing and new products of the Blackburn factory will require an expansion of that factory's labour force.

A 275 kV ISOLATOR

An isolator for 275 kV service has recently been designed jointly by The General Electric Co. Ltd., English Electric Co. Ltd., and Ferguson Pailin Limited to meet the special requirements of the British Electricity Authority.

The first of three manually-operated single-phase units to the new design has now been built by the G.E.C. and is being delivered to the B.E.A. Cable Testing Station at Staythorpe. The switch is of the rotary type with a central single break and is fitted with four-point high pressure contacts with a normal current rating of 1200 amp.

The G.E.C. has orders in hand for some 150 three-phase isolators for various B.E.A. sites throughout the country. Each consists of three single-phase units mechanically ganged in either a parallel or tandem group and arranged for both hydraulic and manual operation. The three-phase isolators will carry a through short circuit current corresponding to 7,500 MVA, and certain of those now being made are fitted with manually operated earthing switches of the same short circuit rating.

BA2

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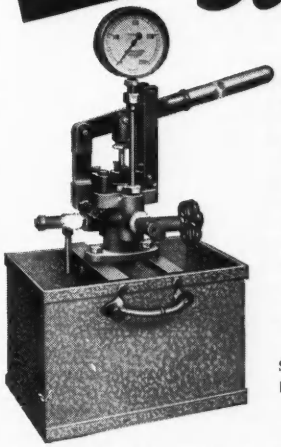

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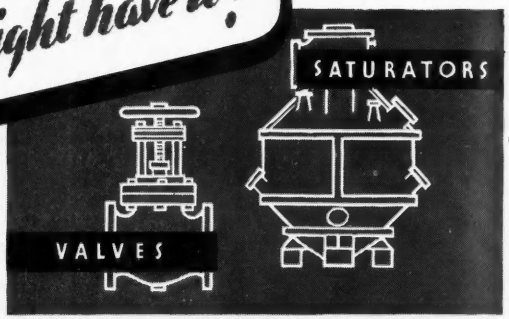

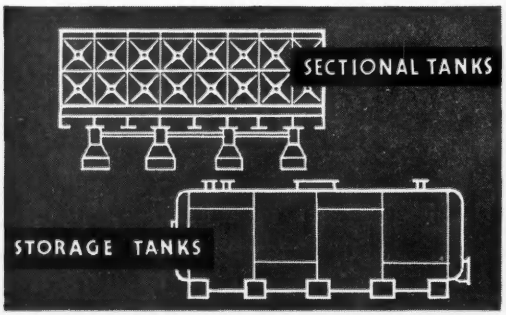

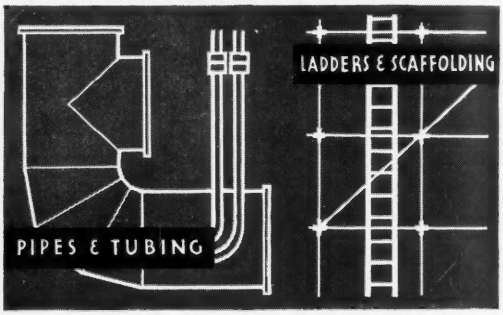

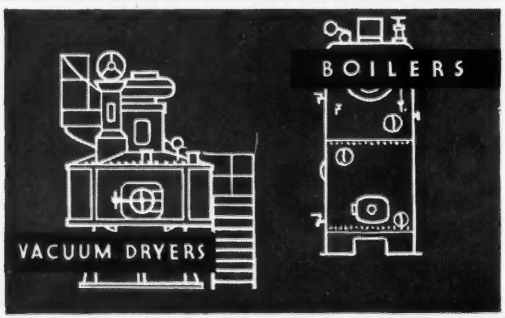

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BT/14

QUALITY IN LIGHT METAL CASTINGS

In times of keen competition there is a strong temptation to lower standards of quality and service, and thus cheapen the product in order to keep up the volume of production. In this article the Light Metal Founders Association point out the dangers of such a course, recognizing that the growth of a young industry such as theirs is likely to be retarded, not accelerated, if short-sighted methods of development are adopted. They urge that, in ordering light alloy castings, buyers should in their own interests always insist on conformity to standard specifications.

Perhaps the most generally recognized feature of the past fifteen years in the field of metallurgy has been the tremendous increase in the volume of output of light metals. The impetus was provided, of course, by the necessity of building vast numbers of aircraft, for which lightness and strength were prime requisites. These twin requirements had to be fulfilled with certainty and precision—there was no room for guesswork or approximation, so materials were described and defined by standard specifications.

Peacetime uses of light metals do not as a rule call for the highest strength/weight ratio, either on technical or economic grounds, but it is none the less essential to make sure of the consistent quality of the materials to be used for any engineering purpose. In 1945 the British Standards Institution issued for the Ministry of Supply the BS/STA7 Services Schedule of Aluminium and its Alloys, which was widely used as a general reference until the publication in 1949 of a series of British Standard Specifications covering aluminium and aluminium alloy products for general engineering purposes.

Though the benefits of standardization apply to all products, in this article we are concerned only with light alloy castings, and an enumeration of the main points affecting castings in particular may not be out of place here. The objects are : to restrict excessive variation of alloys for the convenience of founder, finisher and user alike ; to provide a generally-accepted common reference in the welter of proprietary names ; to enable the customer to appraise the nature of the materials offered, and satisfy himself that they are suitable for the purpose for which they are required ; to define methods of inspection and testing, and to specify the chemical composition and property values appropriate to each alloy ; to establish in advance an agreed procedure to be followed in the event of dispute.

BS. 1490 : 1949 provides the means of attaining all these objects. By careful deliberation a series of specifications has been drawn up to cover a range of alloys that will satisfy all normal engineering requirements. It includes not only the strongest available alloys, used so extensively and successfully in aircraft and wherever lightness has to be accompanied by high strength, but also the more workaday materials that possess adequate strength for lightly stressed articles and are less costly to produce. It also includes alloys which are specially suitable for particular types of service—for example, by reason of their resistance to corrosion, or their retention of strength at elevated temperatures, or their ability to acquire a decorative finish.

The existence of a series of specifications makes it easier to ensure that alloys used are suitable for the purpose which the castings are to serve, both by narrowing the range of choice to include only recognized materials and because the advice of founders that produce castings to specification is freely given and reliable. The importance of choosing the right alloy for any given job is widely appreciated nowadays, but was not always so. For instance, a year or two ago an investigation was held into the failure of aluminium alloy components of public service vehicles built prior to 1939. Nearly all the cast specimens analysed were found to conform to no British Standard as regards composition, or to contain excesses of certain constituents detrimental to performance. Such haphazard ordering of castings would be unusual, and inexcusable, now.

With standardization firmly established the light metal industry in Britain is more fortunate than those in some other countries. It would be a thousand pities if this advantage were lost under pressure from competition. In the present trade recession there is a very real temptation to buy in the cheapest market, with less insistence on quality. Within the last twelve months buyers of industrial goods—materials, semi-finished products, plant and equipment—have become much more price-conscious. The world-wide shortages of both capital- and consumer-goods have now been made up as far as ability to pay for them will allow : with more goods available, the customer is able to exercise discrimination and, with less money with which to pay for them, he will assess values very carefully. This makes it all the more important not to sacrifice quality to cheapness, because we cannot afford to dishonour the tradition of good workmanship that has sold British goods all over the world.

How, then, can competition be successfully met ? Only by careful estimating and accurate costing. The smaller the margin of profit the more vital it is to know exactly what the position is. It would be foolhardy to take chances with materials, when unsuspected defects could upset the most carefully calculated transaction. In the field of castings, especially, the existence of accepted standards provides means of avoiding unnecessary risks.

The meticulous control necessary to ensure conformity with specifications cannot be exercised without expense to the supplier, who has to employ qualified and experienced supervisory staff, and equip them with costly instruments and apparatus. There are many ways in which the cost of castings could be reduced : by using lower grade metal, by relaxing control of melting and pouring temperatures, by less frequent sampling, and less vigorous inspection and testing. To the customer who does not check the quality of castings—and not all are equipped to do so—the deterioration may not at once be apparent, but will almost certainly show up sooner or later with, possibly, dire consequences.

The Light Metal Founders Association exists to maintain, by the free interchange of technical information and by friendly co-operation, a level of quality in light alloy castings worthy of a progressive industry. Its members realize that only by doing so will they be able to develop and enlarge the fields of application of light alloys. Skimping is recognised to be short-sighted and detrimental to real progress, however keen price competition may be. For the individual founder it is far better to lose an order than to win it at the expense of reputation, and for the industry as a whole gains made in the invasion of markets hitherto held by ferrous or other non-ferrous metals cannot be consolidated if they have been won by reckless tactics. But, to some extent, founders are in their customers' hands, and if no value is set on quality control the pressure of competition may force its abandonment.

HOW MUCH IS LIGHTNESS WORTH ?

All aircraft designers are pulled two ways—constantly pressed to put in this or that improving gadget, and constantly called on to keep the weight down. It is a continual compromise, not only for the designer of the aircraft itself but for the maker of every piece of equipment that goes into it.

A pound saved in weight is a pound added to the payload and to the revenue earning power ; but this usually means extra capital cost of construction, because new materials, methods and tools are needed. How much money is it worth spending on costs of construction to save a pound in weight ? The Society of British Aircraft Constructors' Weight Control Panel has made the following calculations as a guide.

Working on assumptions based on normal airline practice, the annual revenue earned by the operator from each pound of payload is £27. So if a designer can reduce the basic weight of a design by 100 pounds, then he is supplying the operator with an extra £2,700 a year in revenue. This figure applies to one aircraft only. If the manufacturer supplies a fleet of ten aircraft, then the extra revenue gained by the airline will be £27,000 a year.

These figures relate to aircraft with the cruising speeds of piston-engined types—about 200 mph. With the event of jet and turbo-prop aircraft, with double the cruising speeds, these revenue-earning figures are immediately doubled, too.

How much does it cost the manufacturer, in extra capital costs, to reduce weight ? The experts have analysed the cost of weight control on the basis of experience with a number of modern airliners and believe that a pound saved adds about £35 to the first cost of the aircraft.

Since an operator gains £27 in a year from each pound saved, he can clearly work off the £35 of capital cost in about 18 months of operation, and over the normal " life " of the aircraft—about eight years—he will earn about six or seven times the initial cost to him.

Obviously it is impossible to assess in financial terms the value of weight saving on a fighting aircraft ; there, every pound saved means better performance. The SBAC Panel has therefore made the following calculations to show the effect of adding ten per cent to the equipped weight of a jet fighter :—

Decreases top speed	2 per cent
Decreases range	11 „ „
Reduces service ceiling	16 „ „
Reduces rate of climb	16 „ „
Lengthens landing distance	29 „ „
Increases landing speed	5 „ „

JET ENGINE TEST PLANTS FOR THE ROLLS-ROYCE AVON ENGINE PROGRAMME

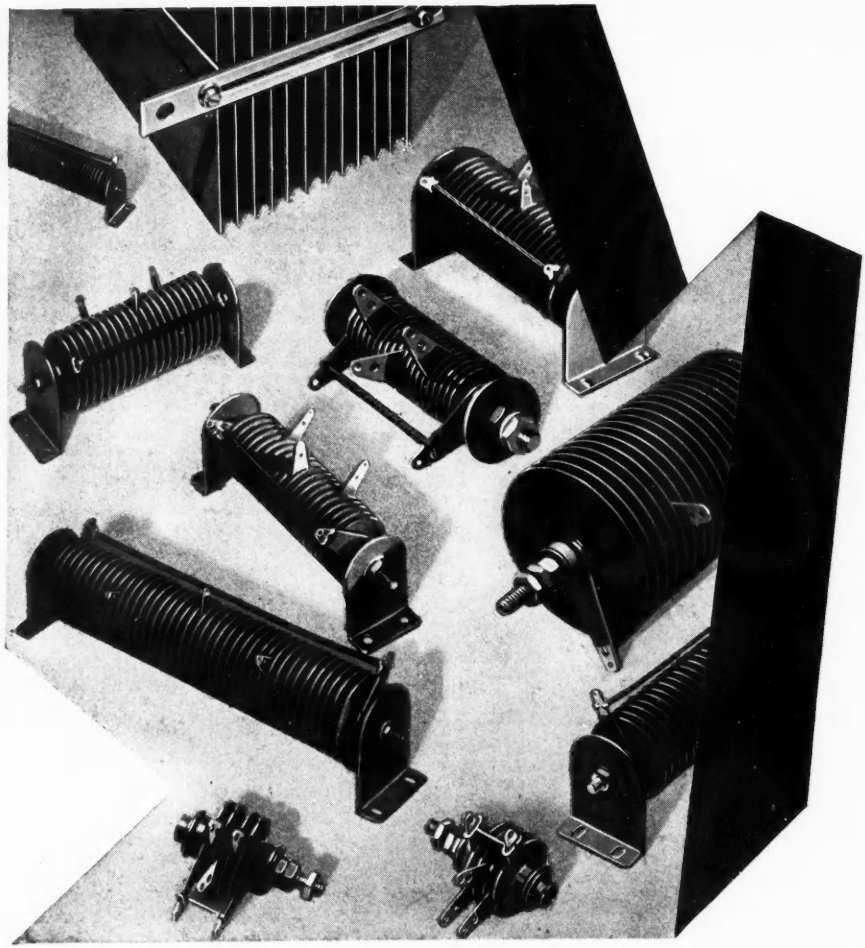
In company with certain other firms, The Standard Motor Co. Ltd. are co-operating with Rolls-Royce Ltd. in the manufacture of the Avon Engine as part of a National programme to supply engines for civil and military aircraft which Britain will produce both for herself and overseas countries. These aircraft include the Hunter, Swift, Valiant, Canberra and Comets (Mark II and III).

The need for test plants for developing new engines or improvements of details, is apparent when one realises the standards set by the civil and military authorities for every engine produced. Even if it is exactly like hundreds made previously, every engine is thoroughly tested before ever it leaves the ground. However accurately the various components of the engine are manufactured and fitted, great care is necessary to ensure that many items are correctly adjusted and that they operate satisfactorily. The performance of the entire engine is also checked, against a specific set of duties and for specific durations of tests. Nothing but such strict attention to details enables the standard of such engines to be maintained.

It is true to say that the Heenan & Froude plants are the first large-scale test equipment built in quantity for a jet engine production programme.

It was apparent that a considerable engineering effort would be involved in the supply of such test plant. Heenan and Froude Ltd. were commissioned to supply as designers and main contractors, the entire test-house installations complete in every detail, not only for The Standard Motor Company, but also for an extension factory of Rolls-Royce Ltd. and for D. Napier and Son Ltd., who are also co-operating in the manufacture of the Avon engine. For the plant at Standards, Heenans made nearly 1,000 arrangement and detail drawings.

Heenan and Froude Ltd., have in the past supplied major aircraft test plants (piston engine) in great numbers both in Great Britain and abroad. Before and during the last war, for instance they supplied, for the re-armament and expansion programmes alone, some 250 such plants, complete in all respects and with all auxiliary



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plant and accessories ready for engine testing to begin. Nevertheless this contract represents a new landmark, as it is the first occasion on which a bulk order has been placed with a single firm for jet-engine test plant " lock, stock and barrel."

In some regards this is not surprising, in view of the secrecy which surrounded jet engines in their early years, and the relatively small numbers in which any one manufacturer produced them. The same circumstances operated to delay the introduction of a standard, universally-accepted test plant, capable of accepting all the major jet engines now being constructed in any country and of giving readings of very high accuracy.

Thus, the Heenan jet-engine thrust cradles in use by Standard are equally suitable for the Bristol Olympus, de Havilland Ghost and Goblin, and Armstrong-Siddeley Sapphire, as well as even more powerful engines of the future.

The layout of the Standard Motor Company plants was dictated to a considerable extent by the necessity of using existing buildings. These were erected early in the last War to house Heenan hangar stands, for testing the radial aircooled piston-type Bristol engines which they produced under the " Shadow Factory " scheme.

In these plants, as the engine power was absorbed by large airscrews, the engines were mounted on nacelles some 10 ft. above floor level, and the Control Room was raised accordingly. The same position of Control Rooms was retained for the jet engine plants.

As this construction provides a clear space below the Control Room floor, advantage was taken to instal a Battery Room and to house the CO_2 bottles, etc.

The building is in the form of a capital letter H, housing two plants and with a common double Control Room. The space at one end is roofed over to create a Rigging Shop, where engines receive their final preparation for erection on the engine cradle. This reduces " idling time " of the test plants themselves.

Great care has been taken to render the change-over from one engine to the next as rapid as possible.

The basic essentials of a jet engine plant are :

(a) A Thrust Cradle, on which the engine is bolted and arranged so that the thrust which it exerts is transmitted to accurate measuring gear, remotely situated in a Control Room. This Cradle is of course " the heart of the plant," upon which the success of the entire test house chiefly depends.

(b) Means of storing, supplying and measuring the fuel consumed by the engine.

(c) A Control Panel, placed behind an observation window in the Control Room, with measuring instruments and controls.

(d) Ventilating and heating plant, fire-fighting equipment, engine accessory loading equipment, and other auxiliary plant.

(e Sound-proofing.

These items are described in more detail below.

The Engine Thrust Cradle is large enough to take bigger engines than the Avon, and capable of dealing with greater thrusts than is actually required for the Avon. The engine is affixed by brackets to a channel-section framework, strongly constructed, which is suspended in such a way that it can move very freely in an axial direction, but is very resistant to sideways movement. The suspension is by means of steel strips, by which the cradle is hung, near each corner, from heavy cast-iron pedestals.

To cater for cases in which the hot gases do not leave the jet-pipe in a truly axial direction (thus setting up a tendency for the cradle to " yaw," i.e. to turn a little sideways) both sides of the cradle are connected to its thrust-resisting levers ; any difference in the forces on each side is compensated by coupling the two sets of levers together by a very strong twist-shaft.

The final lever of the cradle is connected to the thrust-measuring weighing machine by pull-rods. To reduce frictional losses these rods do not slide in bushes, but are suspended from flexible steel strips, very much on the lines of the cradle itself. By suitable leverage ratios, the force reaching the weighing machine is reduced to one seventy-fifth of the thrust exerted by the engine.

The thrust weighing machine itself is in the Control Room. It is an Avery pendulum (springless) weigher, and is connected to the final pull-rod lever by a length of high-tensile steel wire only $^5/_{32}$" in diameter. By the lever system the great thrust of the engine is reduced at this point to such a degree that even this small rod is not unduly stressed ; and it is also arranged to act as a kind of flexible connection, so that the mechanism of the Avery weigher is not strained by any possible misalignment.

To check the accuracy of the readings, checking gear is provided by means of which any desired thrust can be imposed on the cradle. This imposed thrust is itself known with great accuracy, and thus the readings of the main weigher can be checked very closely. This checking process can be carried through very quickly.

The thrust obtained from modern jet engines is so great that exceptionally high accuracy of readings is desirable. Heenan and Froude therefore had to ensure that any error in readings did not exceed one-tenth of one per cent at maximum load. This aim was in fact handsomely surpassed ; on a typical check test, readings were obtained which were no worse at any point than 0·06%, and the average inaccuracy was 0·0225%, corresponding with one part in about 4400.

It should be noted that this test was actually taken with an engine in position ready for running, and thus the inaccuracies include the resistance of the flexible pipes, controls, etc., connected to the engine.

The Fuel System starts with the main storage tanks, sunk in a pit outside the test house buildings. Each tank hold 12,000 gallons. From here fuel is pumped to each plant by Wayne centrifugal pumps, driven by flameproof motors, and similar unloading pumps are also provided. The pumping system incorporates tank contents gauges, filters, recording flow meters, and de-aerators ; all this equipment is being supplied by The Wayne Tank and Pump Co. Ltd. who subcontracted the piping to Daly and Son of Coventry.

Each test plant embodies a fuel cubicle, constructed in brick as part of the main building so as to enclose and isolate it as a safety precaution. Each cubicle contains a mild steel structure carrying Rotameters for instantaneous readings of fuel flow, an Avery-Hardoll flow meter with timing unit, and a Brodie-Kent flow meter for reheat fuel flow. Negretti and Zambra dial-type mercury thermometers and transmitting-type pressure gauges are provided ; Vokes filter ; hydrometer ; and electrically-operated magnetic stop-valve. Heat resisting glass windows permit observation.

Other items include a fuel reclaim tank and contents gauge, and a Rellumit filter is fitted in the fuel feed line at the engine cradle.

It is convenient to mention here the engine oil inhibiting system, which includes a 20-gallon tank, Vokes filter, piping and valves.

The Control Panel is well arranged and well lighted, and is made of folded and welded steel plate of substantial thickness. Apart from the two Engine Control Levers, it is fitted with a large number of instruments. Where the piping or cabling of these passes through the wall into the engine room they are packed with sound-insulating material in a wall-box. A steel plate manifold is fitted on the engine cradle to form a neat and convenient station from which the permanent piping, etc., can be coupled up to the particular engine to be tested.

From the Control Room all operations and tests are carried out, during which no personnel are in the engine room unless with special permission. A large double-glass window allows observation of the engine.

A comprehensive system of fans and ducting ensures the constant removal of all fumes from engine and control rooms ; pump house, and battery room. Special extract fans with flameproof motors enable air to be continuously sucked through the fuel cubicles, this air being warmed to 70° F by heaters.

Suspended heat-diffusers, high-level heating coils, etc., secure adequate working temperatures in the Rigging Shop, Control Room, and elsewhere.

The sub-contractors for this work were The Carrier Engineering Co. Ltd.

Firefighting Equipment consists of a piping system arranged to distribute CO_2 to strategic points in the engine rooms, fuel cubicles, battery rooms, and fuel pump house, and is provided with pull handles and automatic change-over switches interlocked with the gas pipework to shut off the fuel supply, switch off the fan motor(s) of the ventilating plant, and sound an alarm.

This equipment was supplied by The Pyrene Co. Ltd.

To provide means of testing the engine auxiliary take-off drive, two small Froude Dynamometers are fitted to each engine cradle, one on each side, with Rotol special drive shafts. A small Heenan water cooler continuously cools and recirculates the heated water leaving the dynamometers when in use.

Heenan and Froude's supply included :—Main distribution boards, Fuseboards, Batteries, 24 and 96 volt, with rectifiers and relay panels for charging; For engine starting :—Rotax starter panels, High-energy units for torch igniters, Solenoid valves, ignition relays, time switches, desk panels, warning lights and Klaxons, booster coils, etc.

For auxiliaries :—Relay panels, indicator panels, remote push-button stations, distribution boards, etc.

The sub-contractors were Lee, Beasley and Co. Ltd., of Coventry.

Heenan and Froude supplied a 2-ton Morris travelling pulley-block for the engine room, with runway ; a runway for hoist in the Diffuser Exhaust Chamber forming part of the sound-proofing ; a platform and stairways in the engine room, around the cradle, floored with " Safetread " : a steel stairway from the Rigging Shop to the Control Room ; chequer-plate trench covers ; hand-railings, etc.

Sound-proofing was installed by Cementation (Muffelite) Limited, using an Exhaust Gas Diffuser developed by The Bristol Aeroplane Company and manufactured by Heenan and Froude, with the exception of the flared inlet which was sub-contracted to Fredk. Braby and Co. Ltd., of Bristol.

The exhaust gases leaving the jet pipe are led into the inlet of a large steel venturi or diffuser, which slows them up, and recovers part of the energy of velocity in the form of pressure, and also serves the purpose of entraining a considerable volume of fresh cool air so as to reduce the gas temperature.

At the end of the diffuser a large " basket " spreader is fitted to break up the gas stream and to spread it out over as much as possible of the area of the final passage, from which it emerges to atmosphere. In this final outlet passage the mingled gas and air passes through sound-absorbing " splitters."

Similar " splitters " are used at the air inlet to each engine room, but here there is obviously no need for the diffuser.

Owing to the enormous volume of air consumed per minute, the areas of the air passages and of the sound-proofing materials are large.

Specially constructed doors are used for communication between quiet and noisy areas ; at other points doors of lighter construction are used, both types being made by The Chatwood Safe Co. Ltd.

The roof and walls of the exhaust chamber are lined with felted mineral wool, held in position by corrugated aluminium sheeting. Acoustic tiles were used in the Control Room.

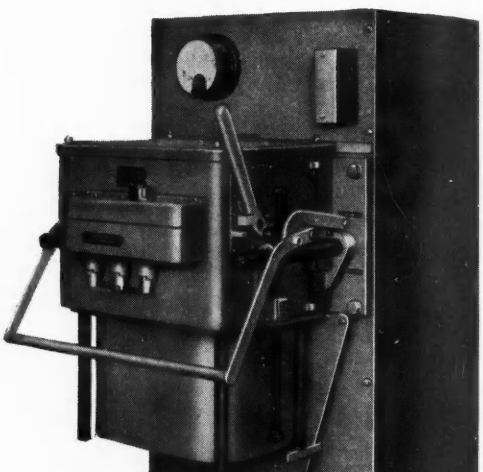
Peanuts or Pullmans?

—whatever your business

The aim of factory management everywhere—whatever the product—is to keep to a production schedule.

Power supply is of the first importance, for neither plant nor light can function without a continuous supply of electric power.

SWITCHGEAR is needed to ensure proper distribution, and where long term ECONOMY is sought—that, surely, is in every works—Ferguson Pailin Type 'K' INDUSTRIAL SWITCHGEAR provides the answer.



Type KC switch unit

TYPE **'K'**

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The type 'K' range of Industrial Switchgear has been designed for use on systems up to 660 volts and for normal current ratings up to 1,800 amps. It fully complies with Factory and Home Office Regulations.

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THE PROTONIC MICROSCOPE

The College of France is now using a new microscope, the protonic microscope, ten times more powerful than the existing electronic microscope. The protonic microscope can magnify 600,000 times. In the apparatus, developed by MM. Magnan and Chanson, the electron charged with negative electricity is replaced by the positively charged proton. The wave length associated with the proton is much shorter, thus giving more separation than that of the electron. Molecules to be examined in the microscope have to be held in balance in a fine mesh metal screen or in holes of a fraction of a micron pierced in metals. Otherwise the instrument is like the electronic microscope. The proton used is that of the hydrogen atom, deprived of its satellite electron by a 100,000 volt discharge.

THE BRITISH PRESSED METAL INDUSTRY

In 1951 a Team of 15 Americans from the pressed metal industry paid a visit to Britain under the auspices of the Anglo-American Council of Productivity and the Economic Co-operation Administration (now Mutual Security Agency). Its objects were, first, " to report all factors that might increase productivity in British stamping plants " ; furthermore, to determine what use had been made of the information obtained in the U.S. by the British Team which visited the States in 1949 and later published its report " Pressed Metal," (British Productivity Council, 2s. 6d.) ; and to take back to the U.S. any information on research, development, engineering or production likely to be useful to the stamping industry there.

This " reverse-flow " Team's report, now makes this cardinal point among the conclusions :

" The difference in philosophy, both economically and politically, between the two countries, and the fact that Britain has been through two devastating wars in twenty-five years make impossible a direct comparison between British and American methods and equipment."

Almost without exception the Team found managers of factories in the British industry to be younger than those in comparable positions in the U.S., yet they carried equal responsibility. " Many who were in no way connected with ownership had worked their way up through the factory by ability and, in fact, any person capable of being a top-flight executive had a chance of becoming one."

Contrary to U.S. practice, " time-and-motion studies are made with emphasis on the time and not much attention is paid to the motion part. These are made primarily to establish piece-rates. There were few work simplification studies being made, so far as the Team could determine, as compared with American standards."

" Standardization, although becoming more prevalent, has by no means reached U.S. standards. It was a common complaint of British executives that their customers would not let them standardize, and many assemblies were noted containing a multiplicity of parts having the same function, but of different designs, that could have been standardized to increase output and lower costs.

In general, there was a lack of cost-consciousness by comparison with U.S. standards. Departmental budgets or foreman's budgets were not common, and ratios for departments were seldom used or compared from month to month or from year to year. The efficiency of many a large company in the U.S. is obtained through such cost-consciousness."

It was noted that the large so-called middle group of medium-sized jobbing companies which is found in the U.S. did not exist in Britain ; consequently internal competition between companies was much less.

Visits to thirteen British plants revealed a wide variation from plant to plant in the technique and equipment used for mass production. In the Team's opinion " the absence of large production runs is the most serious obstacle to the introduction of special-purpose tools and mechanical handling devices.

In most of the plants visited the machinery arrangement was good, but it was felt that " in certain in-line operations it would be desirable to group the machines closer together to facilitate the movement of material from one machine to the other . . . None of the plants visited had made any provision for the re-arrangement of machines quickly and easily, to facilitate production on the particular job being run. It is this lack of facility for easy movement which probably prevents layouts from being frequently altered."

The Team remarks that " one of the outstanding departments of practically every plant visited was the plating and polishing department." It was also impressed with the " Rotodip " process for coating automobile bodies, not hitherto in use in the U.S. " This is an excellent means of providing a rust-preventive coating over the entire metal surface."

Very limited use of standard die sets was noted. The use of such sets, with their attendant advantages, should be greatly extended.

Techniques which were considered as elementary in some plants appeared to be almost unheard of in others. There would appear to be a fruitful opportunity within the industry to raise the general level of productivity by a more free interchange of technical and production information.

BUSINESS EFFICIENCY EXHIBITION

Britain's £45 million-a-year office equipment industry returns to Olympia in June with a bigger-than-ever Coronation Year Business Efficiency Exhibition as a show window for its latest products.

Opening the " Fair " this year on June 16th is Sir Miles Thomas, chairman of B.O.A.C., and taking part will be nearly ninety firms, many of whom will be making a particular effort to emphasise the adaptability and importance of their equipment in the factory as well as the office.

ELECTRONIC CONTROL AND NUCLEAR POWER

" There is no evidence of saturation of electrical utilisation in Britain, and industrial use of electricity will double every 9½ years," said Mr. D. G. Gwyn, B.Sc., A.M.I.E.E., of the South Wales Electricity Board, in a paper to the annual Electricity Sales and Service Conference, organised by the British Electrical Development Association, on May 13th.

Mr. Gwyn said that the present integration tendency which was particularly evident in the steel and coal industries, was resulting in very large amounts of capital being invested in single establishments. Except in cases where waste fuel or heat utilisation, or process steam requirements, made private generation an economic proposition, the large works relied upon purchased electricity. A modern colliery with complete coal preparation and by-product plant required up to 10 megowatts of supply, whilst an integrated steel works with high-speed continuous strip mills could establish a 60 megowatts demand over a thirty-minute period, with peaks of 75/80 megowatts.

" While rapid progress in design and new applications is evident in all branches of electrical engineering, the most phenomenal advances in recent years have been in control developments," said Mr. Gwyn. " Electro-magnetic," photo-electric and other electronic applications in industry have enabled truly remarkable accuracy and consistency to be achieved in the discrimination of time, colour, speed, temperature, size, quantity, humidity, etc. In almost every industry the urgent need for the maintenance of quality and the high cost of labour have prompted industrialists to welcome any reliable form of process control which reduces dependence upon the direct human element.

" The field of control engineering, previously very extensive and specialised, received recent further extension by the application of nucleonics in industry. The new science has been used for air ionisation near machinery generating static electricity, and can be used to provide information upon blast furnace lining wear. Doubtless very many remarkable uses will be developed in the future, and whilst the power consumption of nucleonic control equipment is negligible it is to be welcomed as yet another adjunct in the efficient and comprehensive uses of electricity in industry."

BUSINESS NOTES

The Brush Electrical Engineering Co. Ltd., Loughborough, has opened a new branch office at 14/16 Baldwin Street, Bristol 1. Telephone : Bristol 27000. Mr. J. H. Beaumont Robins, B.Sc., A.M.I.E.E., A.M.I.Mech.E., is manager of the Bristol area.

British Insulated Callender's Cables Ltd. announce that their Lincoln branch office has been transferred to 113 Canwick Road. Telephone : Lincoln 654.

George H. Alexander Machinery Ltd., 82-84 Coleshill Street, Birmingham 4, announce that they have taken over the distribution of the A.B.C. Grinding Attachment, manufactured by Bishop Clark Ltd., Thorneywood, Nottingham.

Henry Waugh & Co. Ltd., 51 Bishopsgate, London, E.C.2, have been appointed to represent The Hymatic Engineering Co. Ltd. in Singapore, Malaya, Thailand, Sarawak, Labuan, Brunei and British North Borneo.

The formation of **Integra-Leeds & Northrup Ltd.,** Birmingham, has been jointly announced by Charles S. Redding, President of Leeds & Northrup Company, Philadelphia, and Maurice Bouffart, managing director of S. A. Integra, Liege, Belgium.

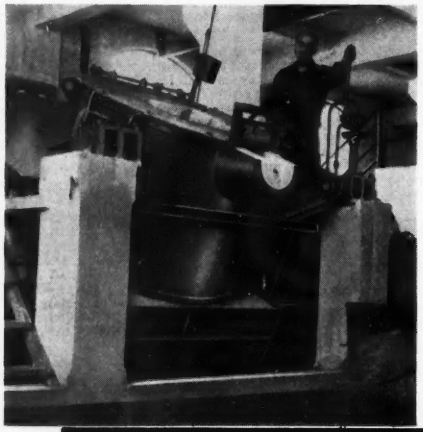
The new firm succeeds to the business formerly conducted in Birmingham under the name of The Integra Co. Ltd., which was a branch of the Liege firm and for some years has been the English agent for L & N products. That business will be expanded to include the manufacture of the products of both Leeds & Northrup Company and S. A. Integra. Ownership of Integra-Leeds & Northrup Ltd. is shared by Leeds & Northrup Company and the owners of the former Integra Co. Ltd. Managing director will be Jean Rogister, heretofore manager of the Birmingham firm. Mr. Redding will be a member of the new company's Board of Directors.

New Economy Engine. In introducing the new " Cost-Cutter " engine for their 2 and 3-ton Thames commercial vehicles, Ford Motor Company Limited have taken an important step in helping to reduce road transport costs. Hitherto, most commercial vehicles in these pay-load classes have been powered by engines which have been designed primarily for larger capacity vehicles, consequently operating costs have been higher than necessary. The " Cost-Cutter " engine has been produced specially to provide highly efficient and economical power in the 2-3 ton range. It is estimated that at least one fifth of the total number of commercial vehicles on the roads of Great Britain to-day come within this class. Heavier Thames vehicles will continue to be powered by the Ford V8 engine, or alternatively the Perkins P6 diesel engine.

The " Cost-Cutter " will go into production immediately. It is a 4-cylinder, overhead valve, petrol engine which develops 70 bhp at 2,800 rpm. It has all the modern features which lead not only to low cost operation, but also to high performance, pulling power, particularly at low speeds, and long life. Close attention has been paid in the design to accessibility and easy servicing.

Production of all Thames commercial vehicles will shortly be accommodated in a new 300,000 sq ft two-floor building which has recently been completed.

Latest designs of mains frequency core type



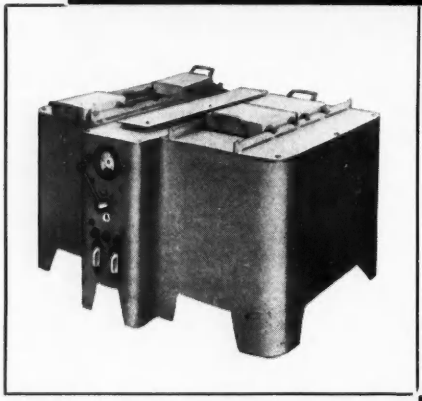
Induction Melting Furnaces

now available in Great Britain

for aluminium and other light metal alloys with outputs of 100 to 1,750 lbs. per hour and for copper and its alloys with outputs of 50 to 4,000 lbs. per hour.

Among the many advantages of the

GWB-A.TAGLIAFERRI furnaces

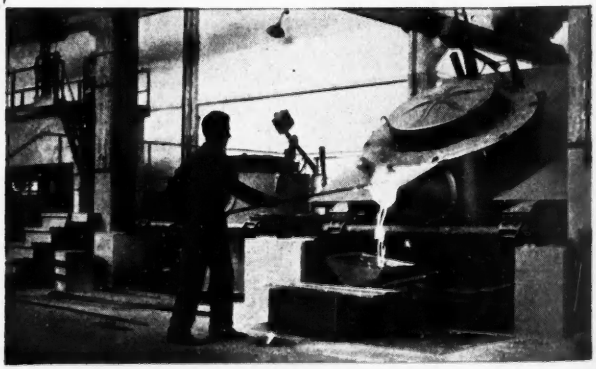


are the following:-

1. Initial starting without using hot metal.
2. Positive metal circulation without turbulence gives maximum refractory life.
3. Special channel design on furnaces for light metals facilitates cleaning without the need for completely emptying the furnace.
4. The refractory lined casing is easily exchanged with the relined spare without removing electrical connections or inductors.
5. Clear indication is given when end of lining life is approaching.
6. Refractory lining of melting duct can be repaired without dismantling the furnace.

Full details of standard units suitable for all normal foundry requirements may be had on request.

TOP: This unit has hydraulic tilting and is rated at 210 kW.
ABOVE: An aluminium bale-out type furnace with two crucibles having control panel incorporated.
RIGHT: A 300 kVA unit, to melt brass at 2,200 lbs. per hour, bronze at 1,760 lbs. per hour.



Proprietors: Gibbons Bros. Ltd., & Wild-Barfield Electric Furnaces Limited.

G.W.B. ELECTRIC FURNACES LTD.
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